A COMPARATIVE STUDY OF HISTOECOLOGICAL VARIATIONS IN THE OLFACTORY MUCOSA OF SOME LIVE FISHES

Thesis presented for the degree of

DOCTOR OF PHILOSOPHY

In Zoology

at

Bundelkhand, University,

Jhansi

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2002

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I certify that " **A COMPARATIVE STUDY OF HISTOECOLOGICAL VARIATIONS IN THE OLFACTORY MUCOSA OF SOME LIVE FISHES**", is the original work of Shalini Sharma, Research Scholar, Post Graduate Deptt. Of Zoology, Bipin Behari College, Jhansi, and is suitable for submission for the award of the degree of Doctor of Philosophy in zoology of the Bundelkhand University, Jhansi. This work has been done by the candidate under my supervision.

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Acknowledgements

I am highly indebited to Dr. Vijay Indra Sharma, Reader Post Graduate Deptt. Of Zoology , Bipin Behari College Jhansi, for his in-valuable guidance, supervision and for taking great pains in going through , the manuscript critically.

My sincere thanks to Dr. U.P. Singh , Principal, and Dr. A.B.Gupta, Head, Post Graduate Deptt of Zology , Bipin Behari College Jhansi, for their inspiration and encouragement. I am obliged to Dr Gupta, who very generously placed at my disposal, all the departmental facilities, needed for carrying out my project.

Dr. O.P.Yadav has been perennial source of encouragement to me, and even in this project he has not failed to provide his valuable suggestions during completion of this manuscript. My special thanks to him.

I am also grateful to Dr. A.K. Shrivastava, who was always available for help when so ever needed. Dr. A.S.Gurudev and Dr. S.K. Dubey may kindly accept my sincere thanks for their constant encouragements, which was

of great help to me, in tackling the task at hand.

I wish to express my gratitude to Dr. S.N. Zadoo of IGFRI Jhansi for his kind assistance. Special word of thanks to Dr. Zadoo for having kindly permitted the use of the photography equipments of his Cytogenic Lab, without which the present level of photographs would not have been possible.

I shall be failing in my duties, if I do not express my thanks to Mr Deep Narain Saxena for typing out the present thesis accurately and expeditiously, putting long hours, Mr. Ghanshyam Prajapati for helping in levelling photographs and Mr. Dheeraj Kesaria, who managed the printing work.

Last but not the least, my thanks are due to Mr. R.K.Chaturvedi, Lab. Assistant of Zoology Lab of BBPG college Jhansi for his spontaneous help as and when needed during the research work.

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Introduction And Historical Review

INTRODUCTION AND HISTORICAL REVIEW

The fisheries sector has a significant role ensuring food security and nutrition for the growing population of this country, considering this aspect it has become necessary to investigate ecological adaptation of different cell types present in the olfactory epithelium of some live fishes, inhabiting in varied aquatic medium. These may be easily caught in living state and known as potent source of phosphate, calcium, vitamins, proteins, potassium and sodium. Such contents are essentially required for development and maintenance of human population.

Thus, the topic under study is vitally important because histological elements of olfactory epithelium are particularly designed to face prevailing conditions of fishes living in a diverse habit and habitat. Their response is also according to the requirement and reactions facing individually. The olfactory organs of fishes are in constant contact with water current circulating through it along with dissolved particles which is touching this sensory surface and causing reactionary effects accordingly .

These sensory organs play a decisive role in location of food, fright reaction, reproductive behavior and

recognition of co-specific individual. In fishes this is detected with the help of olfactory rosette lying in olfactory chamber. These are of different shapes, displaying varied morphological architectural pattern. Histologically every visceral organ exhibits a definite similar cellular organization plan, possessing different types of connective tissues, basal cells, supporting cells, receptor cells and mucous secretory cells, along with profuse or little ciliation on their peripheral surface. There are also essentially present nutritional, supporting, protecting, neurosensory and vascular elements fulfilling metabolic need of this particular structure. Similarly, olfactory rosette also reveals a set architectural pattern, but whatever extra diversities are seen in mucosal and submucosal region of this visceral organ, demonstrates histoecological adaptation of these specific fishes, living in a particular environment. Besides ciliation, mucous secretory activity is prominently displayed on mucosal zone in a manner of forming interruptions of different shapes and size. This causes formation of variable crupts lying at different depths exhibiting concentration of sensory elements in such formations.

Earlier investigation regarding the anatomy of the olfactory organs of fishes are those of Burne (1909), Allison (1953), Hagelin and Johnels (1955), Kleerekoper and Erkel (1960), Trujillo-Cenoz (1961), Johnson and Brown (1962), Kubiak (1962), Branson (1963), Gooding (1963), Pfeiffer (1963,64), Bannister (1965), Moulton and Beidler (1967).

The generalized review on the anatomy of the olfactory organs of fishes has been published by Kleerekoper (1969), Teichmann (1954) and Hara (1975).

The recognized Indian workers who carried out their research work on the anatomy of the olfactory organ of Indian teleost fishes are those of Kapoor and Ojha (1972a,b, 1973a, b) and Ojha and Kapoor (1971,1972,1973a,b and 1974). Their two papers are also seen on the histology of the olfactory epithelium of Labeo rohita (1973) and Channa punctatus (1974). But except above authors and to some extent Rahmani and Khan (1980) and Singh (1972), no ammountable work on the histology of the olfactory organ of Indian teleost fishes has so far been published. Reviewing the existing literature it is found that the work on the olfactory

organ of the European fishes has been carried out to an extent, but little work has been done on Indian teleost.

Consequently, the present work on the histoecologly of the olfactory organ of certain live fishes has been carried out broadly to provide a basis for the further applied study on this important organ. The present study of the olfactory organ, therefore, gives a comprehensive account of the structure, shape and size of the olfactory rosette, lamellae, nasal cavity and the accessory sacs of some live fishes along with histoecological demonstration in view of bifurcation of lamellae, creation of secondary lamellae, formation of exposed and unexposed crupts lying at variable depths. The goblet cells activity is taken into account causing displacement in mucosal element subsequenty allowing the movement of basal cells.

Histoecological study of olfactory epithelium particularly form this point of view of presence of accessory nasal sacs along with circulation of water current form rosette of each fish is also taken in account. The topographical study of the relationship of brain and olfactory rosette has been studied . The area of both the rosette were calculated and

compaired with the area of both the retinae for making the approximate assessment of the sensitivity of the olfactory and retinal surfaces (Teichmann 1954). The cellular component of olfactory epithelium, receptors, nerve and blood supply has been studied in detail from histological point of view.

Though the olfactory organs of all fishes have common structural plan but they show great variations in accordance to their individual histological architecture . The study of such secondary peculiarities is of immences importance as they demonstrate histological adaptations of olfactory epithelium specialized differently in all fishes under present investigation project. Therefore author carried out her research work on the topic "A Comparative Study Of Histoecological Variations In The Olfactory Mucosa Of Some Live Fishes".

The selected fishes are Rita rita (Hamilton), Anabas testudineus (Bloch),Macrognathus aculeatus (Bloch), The habit, habitat, distribution and identifying character are as follows.

Rita rita (HAM)

Rita rita is found in fresh water throughout the India except in Chennai and Mysore. They are characterized by the possession of hollow, inflated dorsal and pectoral spines. Rita rita is a brownish olive green color fish, which is usually of 46 cms length. It is a solitary and highly predaceous cat fish, living in murky depth of large rivers. Rita breeds during flood and do not migrate beyond few miles. This fish can be sold alive in local markets, as they can retain its viability for a long time after it is taken out of water. The author has collected this fish from Bharari, a fishery farm managed by Chandra Shekar Ajad Agricultural University Kanpur under its extension fishery project at Bharari farm Jhansi.

Anabas testudineus (Bloch)

Anabas testudineus or climbing perch was first made known in a memoir printed in 1797 by Daldrof, a lieutenant in Danish East India Company. The fish derived its name from the legend current in the east, that it climbs palm trees and suck their juices.

Climbing perch are commonly known as 'Koi' and are abundantly found in eustuaries and fresh water of India. Its body is slightly compressed and almost cigar shaped with a wide head. They are green or brown color fishes of length 23-26 cms.

Koi has a remarkable ability to stay out of water for exceptionally long period, hence they are in the habit of migration from pond to pond, when their original homes dries up. Anabas uses their pectoral fin and the spiny edges of its gill covers, as legs for walking. Due to the ability to live out of water, they can be easily marketed alive in moistened clay pot and are popular as fresh and good flavour food.

When in water, perch frequently comes to the surface to breath air, and this method of respiration is so vital that it will suffocate even in water saturated with oxygen, if deprived of access of atmospheric air. It is a voracious carnivore and is reported to leave the water in search of earthworm etc. In south India these fishes are extensively used for stocking, uncleared water. Conditions in which

individual fish is inhabiting. The present author has collected this fish from Bharari fish farm.

Macrognathus aculeatus (Bloch)

Macrognathus aculeatus or Pataya is widely distributed in estuaries tidal rivers and muddy streams in India, particularly along the east coast. Their body is long eel like covered with horny plates each having a tooth in its center.The snout is fleshy, elongated and sensitive with a trilobed extremity. Due to the muddy habit ventral fin is absent while pectoral fin is very short. Pataya are generally brown or greenish yellow color creature with light band along the body just above the lateral line. These fishes are of nocturnal habit and in day time hide in muddy holes with snout protruding out from the burrow, while in evening they comes out in search of food which are mainly worms, insects larvae and small crustacean. Macrognathus aculeatus grows up to the height of 38cm and are wholesome food. In Macrognathus aculeatus unmodified gill secrete a large amount of mucous to keep them moist and fasciliati gas diffusion of some lives when the fish is out of water. This

fish has been collected from Pahooj Dam 8 to 10 Km. away from Jhansi with the help of catchers.

No doubt, that sufficient information regarding olfactory organ of fishes are available, but still our knowledge regarding histoecoligical variation is not up to the mark. Among notable workers only Bertmar (1972) has described the olfactory organ of trout on the basis of ecological adaptation. He found that a species from a certain ecological niches has an olfactory organ, which tends to adapt in a particular environment. He further stressed on the cell population of the olfactory epithelium and defined that blastema cells are basal cells which divided into goblet cells, primary receptors and primary supporting cells. The mention of fibroblast cells has also been done by him .But after reviewing literature it is learnt that no one has demonstrated variable types of crupts bifurcation of lamellae , mucous secretory activity ,secondary lamellae formation and establishing synaptic contact in mucosal zone by different forms are neurons. All such cell population present in olfactory mucosa is designed to face ecological changes, in which individual fish is inhabiting. .

The other notable contributions are those of, Sophie Pereyaslawzeff (1876). He was the first to report the anatomy of two fishes Solea impar and Lophius piscatorius, but this study was coarse and no full paper was available on the said topic.

Blaue (1884) studied the anatomy of the olfactory chamber and rosette in Belone, Exocetus, Trigla, Esox, Umbra, Cottus, Gobius, Gadus. This was an important paper published under the title "The olfactory membrane in fishes and amphibian, in which the generalized anatomy of rosette and olfactory pit was discussed.

Wiedersheim (1887) published interesting account of the stages of degenerations of the olfactory organ of Plectognathus and their change from a simple cavity to a split tentacle, which is fully exposed to the water. The selected Tetradon nigropunctatus, Tedradon immaculatus, Tetradon papua, Tetradon peradalis and Diodon maculatus for this specialized study.

Bateson in (1889) was assigned by the council of Marine Biological Association London to study the

perception of fishes, especially on those, which plays an important role in identifying the food in aquatic medium. Beside the study of other sensory organs he put stress on the study of the olfactory organs of fishes .He studied this topic in a generalized manner and pointed out

i Tubular character of anterior nostril in few fishes that hunt their food by scent (<u>Motella</u>, <u>Cobitis</u>, <u>Solea</u>, <u>Anguilla</u>, <u>Lepedogaster</u>, <u>Conger</u>).

ii The valvular mechanism of the posterior nostril in certain flat fishes.

iii The main type of structure of rosette and the arrangement of plates in the olfactory rosette.

Bateson (1889) on the basis of his study on the olfactory behavior, has divided the fishes into two categories

1. Group of fishes, which hunt their food with the help of vision. He observed that these fishes show no reaction to the smell of food, and do not feed at night.
2. The fishes of this group seek out their food by the smell and never use vision for this purpose. These fishes are mostly nocturnal.

Sloger (1894) presented the idea of water circulation through the olfactory chamber .He reported that the flow of water through the nasal cavity is due to the systematic contraction and relaxation of the accessory sac synchronously with respiratory movement.

Nagel (1894) suggested that the characteristic of olfaction is to receive the sensation from the gaseous substance, so in fishes these sensations are not possible as their life is entirely confined to the aquatic medium. Hence he concluded that inspite of the well-developed olfactory organ in fishes they act as the organ of gastatory sense.

Uexcull (1895) imposed Nagel (1894) idea after conducting is experiment on the sharks. He reported that the shark, whose epithelial lining is deleted, find difficult to locates its food in comparison with others sharks having intact epithelium. The operated shark used to swallow sardines heavily coated with Quinine, which was soon discarded from the buccal cavity.

In (1899) Kyle studied the presences of the accessory sacs in connection with the olfactory chamber and tried to co-relate it with the habit of fish. He concluded that the accessory sacs are not only the reservoirs for water but are also the mucous secretary structures.

In the fishes possessing accessory sacs, the valvular condition of nostril is recorded forcibly drawing water through the chamber. The accessory sac can be separated into three series: -

i. A single sac directed anteriorly from either above or below the rosette.
ii. A single sac directed posteriorly towards the eye orbit
iii. Two sacs (ethmoidal and lachrymal nasal sacs) with very definite relation to the ethmoidal and lachrymal region of the skull.

Herrick (1908) in his researches on the nervous system of the olfactory and gastatory senses, distinguished them on the basis of the reception of stimulation .He demarcated the olfactory sense as the distant receptors, where as the gastatory sense is localized on the oral cavity and can

be perceived only by the touch of the material of gastatory sense.

On studying thirty- two families and fifty -two genera of teleosteon fishes Burne (1909) concluded that olfactory chambers comparatively differ little in shape and size. Nearly in every case, olfactory rosette occupies a fixed position with regard to the bones of skull and are lodged in a hallow ethmoid between the point of articulation with the palatine and the lachrymal bones. He further reported that nostrils are the most variable part of the olfactory organ, but their variability is co-related with the natural affinities. The anterior nostril lies directly above the rosette, so that the water can directly pass over the olfactory epithelium. In lower vertebrates generally this opening is tubular.

In certain fishes of Cyprinidaen and Gadidae group, a valvular flap is formed as the hinder wall of the tube, while in other groups of the genera (Esox, Merluccius, Clupidae, salmonidae) the flap is replaced by the singular downward prolongation or curtain that hangs into the olfactory cavity above the center of rosette. This study led Burne (1909) to identify four types of anterior nostril:

(a) Simple Perforation

(b) Tubular

(c) With posterior hood

(d) With internal curtain.

In the same manner shape and size of posterior nostril also depend little upon natural affinity. These nostrils can be of two types :

(a) Simple perforation flushed with the surface of the skin of head.

(b) It is a slit or pinhole, which remains closed by valves.

The outline of this nostril can either be circular, crescentic or oval and the latter forms are observed in many group but they cannot be treated as a characteristic for those groups.

Burne (1909) also identified four types of olfactory rosette in teleosteon fishes which he arranged in columns and types of Basteson (1889):(1) This type of rosette is oval in shape and is commonly observed in the fishes studied by him (Batesons, 1889 rosette type 3; Burne's 1909) rosette column 1); (2) Second type of rosette is circular in shape and is found

in Cyclopterus, Bovichthya, Cottus, Esox, Crestias. It is provided with lamellae radiating in all directions_(Bateson's 1989 rosette type 3;Burne's 1909 rosette column 3), (3) Third type of rosette is elongated with their lamellae arrange in parallel series at right angle to it (Bateson's 1889 rosette type 2;Burne 1909 rosette column 2) .In most of the Eels, to a less extent in siluroids and soles such rosette are observed. (4) This type of rosette is with transverse excess to the internal line and the lamellae are attached to its posterior border in parallel series (Burne 1909 column 4). Such rosettes are observed in Ophicephalus, Hippoglossus and Pleuronectus. The shape of the lamellae is also subjected to great variations from species to species. Burne (1909) placed the lamellae of Gadus in its starting series and rosette bearing such lamellae is categorized under Burne's (1909) column 5.Second type is linguiform bearing lamellae where the suppression of the peripheral part of the lamellae leads to the exaggeration of the linguiform process which is a particular characteristic of the Salmonidae and Clupidae (Burne, 1909,column 6). Third type of lamellar modification is of very sharp convex lamellae, which is found in Mugil, Sphyraena and the triangular lamellae of Eel is also included in this series. Suppression of linguiform process causes the lamella to

become gently curved or with straight free borders and this is observed in <u>Esox</u>, <u>Mormyrus</u>, <u>Clarius</u> (Burne, 1909, column7).

Parker (1910-1911), Sheldon (1911), Copeland (1912) further demolish Nagel's (1894) idea after conducting different experiments on fishes and prove that the sense of olfaction plays a major role in location of food in aquatic medium. The olfactory of fishes are represented by a pair of olfactory pit, which is located on ventral surface in sharks and rays, while on dorsal surface of head in sturgeons and bony fishes.

Each pit opens out side by two openings, anterior in let and posterior outlet. In some species the posterior outlet directly opens in mouth .The olfactory pit is lined by olfactory epithelium which possess finger like folds called lamellae .The olfactory organs are diversely developed, at one extreme they are well developed and at the other they are poorly developed. On the basis of the olfactory ability, Frisch (1941) denominated fishes in two groups; macrosmates and microsmates and this classification is also accepted for animals of other vertebrate group. In Holocepholid <u>Chimeara</u>

monstrosa the olfactory chamber communicates dorsally with the naso-oral groove. The formation of naso-oral groove is due to the extension of two external nostrils, along the upper lid towards the mouth cavity, while the mouth is closed, water passes through the external nostril along the naso-oral groove and through the internal nostril into the mouth cavity.

It is reported by Holl (1973) that since the olfactory chamber communicates dorsally with the naso -oral groove it is always supplied with water.

The wide variation in the location, size, structure and degree of development in the teleoste fishes has been reported. Burne (1909), Liermann (1933), Matthes (1934), Teichmann (1954), Holl (1965), Singh (1972), Zeiske (1973,1974) have presented a generalized account of the olfactory organ of fishes, although there is no extensive review on the nasal anatomy of all species. The study of single species of teleost fishes was carried out by Laibach (1937), Eaton (1956), Jhonson and Brown (1962), Branson (1963), Pfeiffer (1963,1964,1968,1969), Devitsyna (1972), Kapoor and Ojha (1972,1973 a, 1973 b), Ojha and Kapoor (1971,1972,1973a, 1973b, 1974) and Rahmani and Khan

(1977,1980). Kleerekoper (1969) and Hara (1975) published a review on the anatomy of the olfactory organ of fishes and presented critically the anatomical peculiarities of the olfactory organs of some groups of fishes on the basis of previous literature available.

According to Hara (1975) paired olfactory pits are situated on the dorsal side of the head and fishes like Eels and Morays are provided with long olfactory pits extending from tip of the snout to the eyes orbit. Such fishes have most acute sense of smell while Tetradontiformes have regressed capacity of smell as their olfactory pits are totally abolished so nasal laps are exposed to the water. Marshall (1967) reported that bathypelagic fishes show sexually dimorphism in the olfactory organization .The males have large well-developed olfactory organs while female have small and regressed one.

Teichmann (1954) collected data regarding the number of lamellae and concluded that the number increases to some extend with the length of fish. With the formation of new lamella, increases in size, thus the area of olfactory epithelium considerable increases with the formation of new

lamella and by the growth of those already present. Teichmann (1954) was the first person that reported the presences of the secondary lamellae in Rainbow trout, but confused them as the artifact of preservation. Pfeiffer (1963) observed the same secondary lamellae in Pacific Salmon, and Rainbow trout and thus the existence of secondary lamellae was established. According to Pfeiffer (1963), Bertmar (1972), Hara et.al. (1973), Bashor et.al (1974) secondary lamellae increases the area of olfactory epithelium but they are devoid of receptor cells. Teichmann (1954) further made attempts to established a relation between the area of total olfactory surface and those of two retinae On this basis he classified the fishes in three groups:

i. Species in which eyes and nose are well developed (Phoxinus and Gobio).

ii. Species in which eyes is better developed than nose (Esox and Gosterasteus).

iii. Species in which nose is well developed as compare to eyes (Lota and Anguilla).

However the distribution of the receptors on the olfactory surface does not have any definite relation, therefore they are

hardly of any authentic value. Holl (1965) reported three types of sensory epithelium of the olfactory surface:

i. Continuous except for the dorsal part of the lamellae (Ictalurus, Anguilla, Perca, Salmo)
ii. Separated in large area between the lamellae (Esox)
iii. Dispersed in small Islets (Phoxinus, Cyprinus, Carassius).

The great variations are reported in the arrangement of the folds of olfactory epithelium, which vary from species to species .It is very commonly observed that restro-caudally elongated raphe is present in most of the fishes, which provide place to olfactory folds for attachment in the central part of the olfactory rosette .The variations in the number of lamellae in few species was reported by Wunder (1957) as two in Gasterosteus aculeatus; 9-18 in Esox lucius;11-19 in Thymellus articus;14-18 in Salmo gairdneri; 30-32 in Lota lota, 60-90 in Anguilla anguilla. Shibuya (1960) and Pfeiffer (1964) recorded 80 to 90 and 230 lamellae in Channa arqus and Haplopagarus quentheri respectively. Hara et.al (1973) recorded 12 to 14 and 12 to 16 lamellae in Salvelinus fontinalis and Coregonus clupeaformes. It is critically studied

by Kapoor and Ojha (1972a,b, 1973a,b) and Ojha and Kapoor (1971, 1972, 1973, 1974) that lamellar development is always from anterior side to posterior side .It is therefore concluded, that posterior lamella is oldest and largest .No addition of lamella is reported to the lateral ends and number of lamellae depends upon the size of the animal.

The shape of lamellae is also variable from species to species. In some cases like Salmonidae, Clupeidae the lamellae bear linguiform processes, where the suppression of the peripheral part of the lamellae leads to the exaggeration of the linguiform process. Suppression of linguiform process causes the lamellae to become gently curved or with straight free borders, as seen in Mermyrus, Clarias, Esox and Orestias. In Mugil, Perca, Pegelus or Sphyraena the lamellae are sharply convex but triangular in Eel .In Percesoces the lamellae are entirely absent .The degeneration of nose is noticed in Laphius where few lamellae are present, which are parallel to each other.

Eaton (1956) reported in the Centrachide fishes the epithelial fold radiated in spoke like form, from the region of approximately under the anterior nares. In these fishes two

accessory pouches opening from the posterior part of the primary nasal sacs act as water pump during the protraction and retraction of the upper jaw. Liermann (1933) and Eaton (1956) termed the accessory sacs as 'ethmoidal' and 'medial' pouches.

The idea of water circulation through the olfactory chamber was given by Solger (1894). He concluded that due to alternate expansion and contraction of the accessory sacs, water flows in and out of the olfactory cavity and the movement of the olfactory sacs are synchronous with the respiratory movements of the fish.

Pipping (1926) observed that the olfactory capacity is very much related with the nature of transportation of water circulation through the olfactory chamber .On the basis of this relationship the author divided the fishes in four groups:

i. First group includes those fishes in which the flow of water passes through the olfactory sacs only at the time of forward movement of fish.

ii. In the fishes of second group movement of water is caused by the pumping action of accessory sacs, where

water enter and exit through both the nostrils i.e. unidirectional flow of water is absent

iii. In the third group water movement is unidirectional, created by the pumping action of the accessory sacs synchronized with the respiratory action supplemented by the ciliary movement of the olfactory epithelium.

iv. In the fourth group of fishes water circulation is carried out through the olfactory chamber along with the respiratory movement supplemented by the ciliary action of the olfactory epithelium.

The passage of water current is unidirectional. He further specified that fishes belonging to fourth group have highly developed sense of olfaction, which plays significant role in the recognition of food. In the fishes of first and second group, olfaction is weakly developed and does not contribute in the location of food in the aquatic medium.

According to Doving et.al (1977) and Doving and Thommeson (1977) the water circulation through olfactory chamber is technically denominated as :Isosmates and Cyclosmates types. In the former group ciliation of olfactory epithelium is responsible for the water circulation through the

olfactory chamber, whereas in latter group compression and expansion of the accessory sacs in relation to skull bone, bring about the transportation of water through the olfactory epithelium. But this denomination of Doving et.al (1977) was further corrected by Derivot and Godet (1979). They clarified the Isosmates nominclature of Doving et.al (1977) in the form of Heterocyclomates and Auto-cyclomates. In the former group fishes are dependent on respiratory movement for the circulation of water through the olfactory chamber, whereas in the latter group ciliary action is solely responsible for creating the water current through the olfactory chamber.

Rahmani (1979) in addition to Doving et.al (1977) further elaborated the classification of fishes with regard to the circulation of water through the olfactory chamber and he put forward another denomination as amphisosmates besides cyclomates and isosomates. Here the ciliary movement as well as the pumping activity of sacs brings about water transportation. The remarkable observation is the presence of window in some lamellae of Closia fasciatus which faciliates easy water circulation through the olfactory rosette.

Rizivi <u>et.al</u> (1984) studied the olfactory organ of a fresh water fish, <u>Mystus vitatus</u> and recorded this fish as macrosomatic species with predominantly developed olfactory faculty. They reported unidirectional entry of water in the olfactory chamber, which is carried out by the ciliary movement of olfactory lamellae.

Waghray (1986) reported sexual dimorphism in Electric Ray on the bases of shape and size of the olfactory organ. Waghray (1986) found kidney shaped and more rounded organ in male while slightly elongated and narrow in female.

Our knowledge pertaining to the histology of the olfactory organ is very meagre. However some important references in this regard are those of Hopkins (1926), Kolmer (1927), Allison (1953),Trujillo-Cenoz (1961), Branson (1963), Gemne and Doving (1969), Kleerekoper (1969), Ojha and Kapoor (1973), Kapoor and Ojha (1972 c) and Hara (1975). Our existing knowledge reveals that the plan of olfactory epithelium of the fishes is not very much different as compaired to those of other vertebrates.

Kleerekoper (1969) described all the cell types and their fibre connection in the olfactory epithelium. Schultze (1856) recognized following types of cell in the olfactory epithelium of vertebrates: receptor cells, supporting cells and basal cells. The presences of sensory and supporting cells in the sensory epithelium of fish, as in other vertebrates, was also observed by Grimm (1873). Dogel (1886) distinguished three forms of sensory olfactory cells: filamentous, rod shaped and cone shaped. In some species, large flask shaped mucous cells are observed which are interspersed among the supporting cells. The presence of mucous cell in the olfactory epithelium of other vertebrates shows variation in minor detail within a particular organ. They are filled with secretory substance, which is seen extruded out in the interlamellar spaces. Papova (1966) also reported the presence of mucous cells among the supporting cells.

In addition to usual cell types, new cellular elements such as secondary neuron or spindle shape cells and primary neurones or rounded cells have been identified by Kapoor and Ojha (1972c) in Channa punctatus and Ojha and Kapoor (1973) in Labeo rohita.

Devitsyna (1972) compaired two marine species, sea cod (Gadus moruha) and Novaga (Eliginus novaga) with a fresh water member of the family Gadidae Barbot (Lota lota) on the basis of the histological structure of the olfactory epithelium and bulb. He characterized that quantitative distribution of receptor cells along the surface of folds is irregular in all three species and this is reflected in their concentration in some parts with their thinning out in others. However the general pattern of the quantitative distribution of the sensory element over the olfactory fold is characterized for each species.

Thornhill (1972) reported the structure of accessory olfactory organ of Lampetra fluviatilis, which consist of cluster of inter connected vesicles in tenuous connection with the exterior medium via the cavity of olfactory organ .The wall of the vesicles is composed of two type of cells which are designated as light and dark cell, primary sense cells supporting cells (Hagelin and Johneles (1955) and Thornhill (1972)). The primary sense cells, which are responsible for the sensation of smell, are provided with peripheral nuclei with their axon directly passing to brain. They differ from olfactory sense cells in the size and number of cilia .It is

therefore concluded that accessory sense organ of Lampetera is capable of responding to a special kind of chemical stimulus. Contrary to the finding of others, Thornhill (1972) suggested that the accessory olfactory organ is morphologically similar to the olfactory epithelium.

Zeiske et.al (1976) studied the epithelium of the olfactory organ of the Cyprinodontoidae species by transmission and scanning microscopy .The relatively flat floor of the organ is covered by sensory and non-sensory epithelia. Non-sensory epithelium separates the distinct area of sensory epithelium. Difference between the two olfactory organ of Xephophorus heleri and Aplocheilus linectus was found to be related to the topography and quantitative distribution of epithelia. The non-sensory stratified squmous epithelium contains numerous goblet cells and surface cells with microridges. The sensory epithelium bears basal supporting and two types of sensory cells i.e. ciliated and microvilous receptor cells.

Recent researches dealing with the epithelia of olfactory organs of fishes based on electron microscopy, reveal that four cell types are present in the olfactory

epithelia of Neoceratodes forsteri i.e. olfactory receptor cells, supporting cells, nonsensory ciliated cell and basal cells. Goblet cells may also be present but their shape, size and secretory habit differs variably from species to species. The essential features of the olfactory receptor cells of Neoceratodes are the presences of microvilli and cilia (Theisen1972).

Recently Yammato and Ueda (1977, 1978 a, b, c, d, e, f) described the order Salmoniformes, Clupeiformes, Cypriniformes , Gasterosteiformes,Channiformes,Synbranchiformes,Anguilliforme, Myctophiformes and adopted scanning microscopy process in describing ultra microscopic structures of the olfactory epithelium of the representative of the above orders.

Their main stress was on the different types of ciliation and intercellular contents of the cells of the olfactory epithelium. They described following types of cells on the basis of their surface specialization; cell bearing many long cilia on wide and flat surface (type I ciliated cells), those bearing several short cilia which projects radially from the round cell apex (type II ciliated cells), those bearing no cilia

but tuft of numerous microvilli (microvillus cells), those bearing neither cilia nor microvilli but protruding as a simple rod from surface (rod cells). Their internal structure are reported to have similar internal micro - organelles .On the basis of surface specialization in the olfactory epithelium.

Yammato and Ueda (1978e) reported that fish with dense cilia arising from type one ciliated cells are believed to have predominantly developed olfactory sensitivity such as Eels (Schulte (1972); Yammato and Ueda (1977)) and Cod (Lowe and Macleod 1975). Contrary to this, fishes having less developed olfactory sensitivity where epithelium lacks type one ciliated cells and cilia are dispersed into small islets such as Atheriniformes (Zeiske et.al (1976); Stickle backs (Bonnister, 1965;Yammato and Ueda (1978d)).

Pandey and Misra (1980) studied olfactory apparatus and reported that in C. mirgala and Labeo rohita lamella are double layered and bears central connective tissues consisting usual cell type in the form of receptor, supporting, basal and goblet cell. They have tried to classified olfactory rosette of C. mirgala and Lobeo rohita according to Bateson (1889) and

Burne (1909). They have also described these fishes as eye-nose fishes according to Teichmann (1954).

Sharma (1981) reported that the olfactory epithelium of lamellae exhibits cellular activities like budding, detachment, cellular extrusion, curving and the migration of mucous secretory goblet cells in the fishes chosen in his research work.

N.Rizvi and S.M.Khan (1981) give a comprehensive account of the olfactory flap of Tetradon patoca (Linn). The olfactory flap is situated on the dorso lateral surface of the snout. They reported that anterior and posterior flaps are generally of unequal size and joins at base without any tube formation from the apical margin up to one quarter of the entire length of the flap. There are hexagonal areas which are almost equal and are compactly arranged. The count shows that 14-16 hexagonal areas are present in slightly overlapping flap in the fishes.

Singh and Singh (1986) carried out their investigation on the olfactory organ of four hills stream fishes. They reported that the olfactory epithelium is composed of ciliated

cells, microvillus cells, supporting cells and pigment granules. Rod cells were found only in the lamellae of Schizvthorexrichardsonee. Apertures or holes and tufts of microvillus cells were also observed in the olfactory lamellae of Puntius chilinoides.

Sinha and Sinha (1986) reported that in Sphyraena jell (c) the olfactory organ consist of a well-developed rosette and an accessory nasal sac which is situated ventrally. The olfactory rosette is oval and belongs to Burne's (1909) rosette column I and Bateson's rosette type 3 and classified it with Teichmann's (1954) group I i.e. "eye nose" fishes in which eyes and nose are equally developed. Sinha (1986) has also described the functional anatomy of the olfactory organ of Sicamugil cascasia (HAM) in which the two accessory nasal sacs are situated dorsally and ventrally to the main olfactory chamber. The author studied the mode of working of the accessory nasal sacs and its role in effecting replacement of water in the olfactory chamber of the fish.

Kashiwayanagi et.al (1987) reported the changes in membrane potential and membrane fluidity in response to

various odorants in a suspension of Porcine olfactory mucosa.

Doroshenko and Motavkin (1987) observed variations in number and arrangement of the olfactory rosette folds, as well as in olfactory epithelium, which they named, as receptory and indifferent epithelium. They further pointed out that olfactory epithelium interspecifically varies greatly in the arrangement of receptor and secretory cells. In the nasal cavity, the roof and adjacent upper walls are lined by olfactory mucosa, which consist of a pseudostratified columnar epithelium resting on the supporting connective tissues. The olfactory epithelium contains three major cell types, which are easily identified on the basis of location of nuclei, which distinguishes them from cytoplasmic zone. They are

i. Sustentacular cells in which nuclei is located in the most superficial part of the nuclear zone. These cells extends through the entire thickness of the epithelium and don't contain cilia.

ii. In Basal cells the nuclei is situated in the deepest part of the nuclear zone, immediately adjacent to the connective tissues and have only a small amount of

cytoplasm, which is confined to vicinity of the nucleus and doesn't reaches the surface .In this zone mainly there is a supply of lymphoid wandering cells and macrophages, some of which move into other zones and phagocytize dead or degenerating cells.

iii. The receptor cell nucleus is located in the broadest part of the nuclear zone. These cells contain a distal process that extends from the perikaryon to the surface where they possess a bulbous expansion called the olfactory vesicle. The proximal part of the receptor cells extends towards the basal region of the olfactory layer where it continues as a slender axon and along with the axon of other receptor cells.

Yadav (1988) studied the histomorphology of the olfactory organ of fresh water fishes. He reported that the variation in the cellular composition of the lamellae, not only occurs in different fishes but also in the lamellae of the some rosette of an individual fish. The author also reported deepenings and elevations in the olfactory epithelium and concluded that former one is the form of crupts, which are richly supplied with primary neurons, and takes the shape of "olfactory bud".

Dubey (1991) after doing comparative histological study of olfactory epithelium of Colisa fasciates (Bl and Schn); Clarias batrachus (Linn) and Chanda nama (Ham) concluded that lamella is provided with number of microformations in the forms of cell ball, curving, mucosal inpushings and number of structural variations.

Singh et al (1996) described the olfactory organ of Illisha motius (Ham) reporting oval olfactory rosette bearing club shaped median raphe and quadrangular shape of lamellae. They also tried to co-relate different ecological habit of fish Illisha motiusand suggesting this fish having equally developed eyes olfactory system operating promptly in the procurement of food from the environment.

Calzada et al (1998) described similar histological picture in the development stage of the larvae of Spanis aurala and found ciliated and non ciliated cells along with mucus secretory activity in a submucosal zone.

Calzada dal (1998) described similar histological picture in the developmental stage of the larvae of Sparus aurata and

found ciliated and nonciliated cells alongwith mucus secretory in its submucosal zone.

Sharma et.al (1999) reported the abundance of aquatic resources, diversity of species, compactability with their forming system and an upcoming activity. Histoecological study of olfactory organ will also demonstrate to sketch out such sustainability in bio-physico-chemical variables, encountering in the habitat of a particular fish.

Sharma et.al (at press) reported socio-economic culture technical factors of fishes encounter in various aquatic environment. The environmental conditions to a fish are also been influenced with histoecological factors of olfactory epithelium.

Dr. Gautam & Gautam (2000,2001,2002) specifically demonstrated the pesticide effect on the cellular composition of gastro intestinal damaged by different toxice contents present in water.

Such effects may be visualized in the olfactory mucosa too as water is constantly circulating through the olfactory

chamber, which may be bearing some pollutants. Now a days no water is free from pollutends and histoecologically the olfactory epithelium is so designed to get it automatically protected by such pollutents effects. Olfactory mucosa in Rita rita , Anabas testudineus and Macrognathus aculeatus is richly supplied with mucus secretory device and heavy ciliation. Besides in Rita rita, Anabas testudineus and Macrognathus aculeatus in which additional accessory sac pollutened intensity may get reduced prior to the circulation of water through olfactory epithelium . Present study emphatically demonstrates that formation of different types of crupts at different olfactory level, ciliation presence of mucus secretory trees are the device neutralized the polluteing effects and also create enhancement in receptory surface of olfactory mucosa.

Material & Methods

MATERIAL AND METHODS

Large amount of Macrognathus aculeatus of different sizes were collected from Pachooj Dam in Jhansi .Rita rita and Anabas testudineus were obtained from Bharari Fish Farm house in district Jhansi.

The author has collected the above mentioned fishes in living state and kept them in aquarium for experimental uses.

The observations were made under stereoscopic binocular microscope. The olfactory and retinal areas were calculated by the Teichmann (1954) method. Prior to the separation of the olfactory lamellae, the rosettes were kept in 70% alcohol, which causes stiffness in the lamellae. This allows easy detachment of the lamellae without any damage from raphe and the floor of olfactory chamber. First of all the rosette is cut into two halves through the raphe by sharp blade and then lamellae are gradually separated one by one from anterior side.

Lamellae were mounted temporarily in glycerine and their actual areas were measured by the planimeter. The total area of one half is multiplied by two and thus the value of area of one rosette is calculated . But in case of Anabas testudineus and Macrognathus aculeatus the olfactory area is not doubled because of the fact that this fish is raphless and arrangement of lamellae in it rosette is in a single row.

The area of eye is measured by Planimeter as well as by applying 22/7r^2 formula where ‘r’ is the radius. Ecological coefficients by area methods were calculated by the following formula: -

$$= \frac{\text{total area of olfactory lamellae} * 100}{\text{total retinal area (both the eyes)}}$$

Similarly ecological coefficient calculated by brain lobe method can be drawn by the following formula: -

$$= \frac{\text{length of telencephalon} * 100}{\text{length of mesencephalon}}$$

For histological studies the olfactory rosette and accessory sac were taken out from the narcotized specimens and were fixed in Bouin's fluid for 6-24 hours depending upon the tissues. Transvers and horizontal sections were cut out at 6-8um in thickness and stained with Mallory's Aniline Blue Collagen stain and Delafield's Haemotoxylin and then counter stained with Eosin.

To study the water circulation through the olfactory chamber Alizarina Red solution was injected by hypodermic syringe from both anterior and posterior nasal opening to study the ingress and egress of the water. It was observed that the red solution was seen coming out from posterior nasal opening establishing unidirectional flow of water (from anterior nasal opening to posterior). Similar results were also obtained by injecting carmine and chalk particles when it was repeated on preserved specimens in which the jaws were mechanically opened and closed.

Observation

Plate – 1 Photograph of dorsal view of the Rita rita showing position of nostrils.

Plate – 2 Photograph of median dorsal view of dissected head of Rita rita showing both the rosette inside and the exposure of ventro lateral accessory sac.

ANT. NAS. TUBE	Anterior nasal tube
EY	Eye
NAS. BAR	Nasal barbel
POST. NAS.OP	Posterior nasal opening
RE	Rosette
RPH	Raphe
VEN.LAT.ACC.NAS.SAC	Ventro lateral accessory nasal sac.

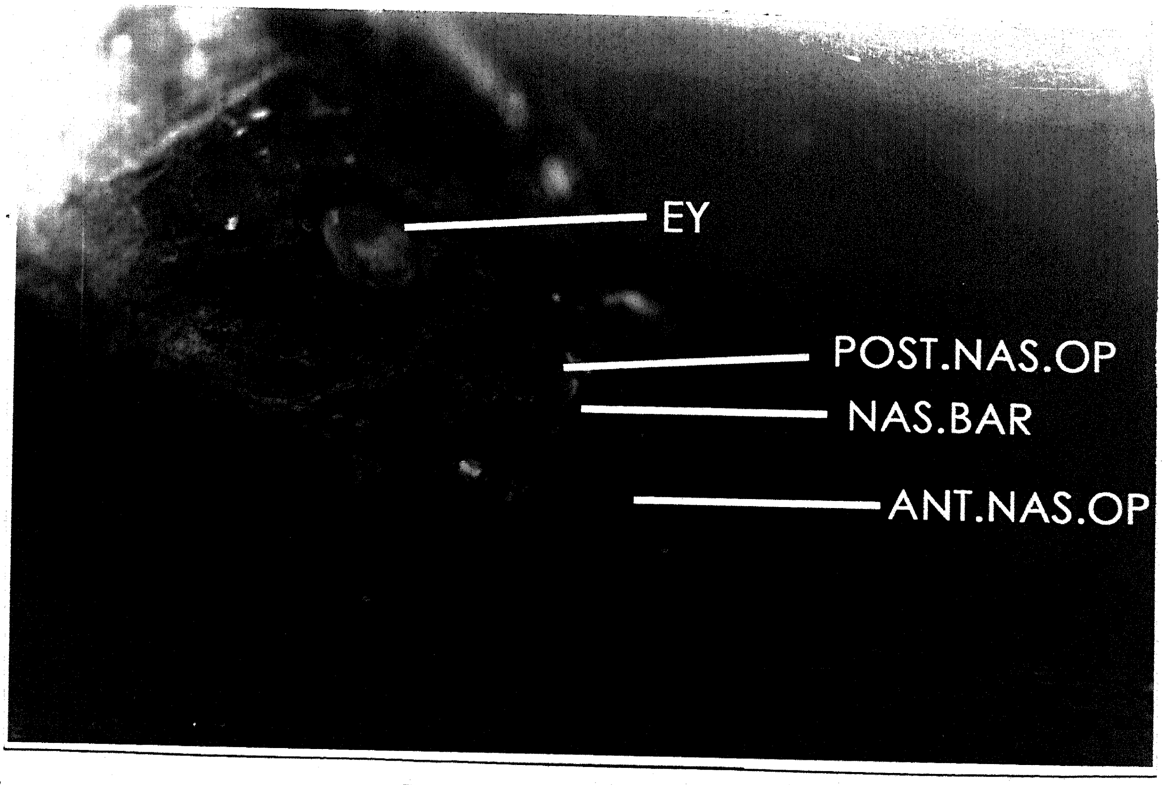


PLATE - 1

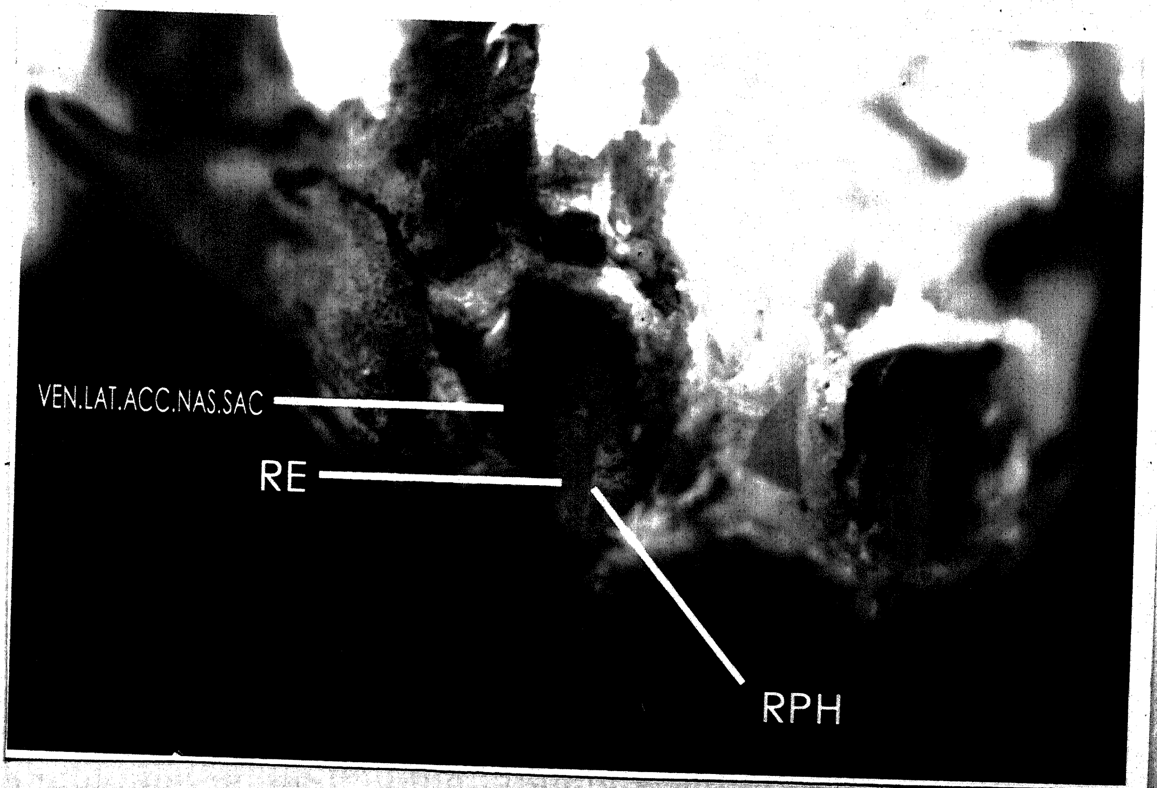


PLATE - 2

Plate – 3 Camera lucida sketch of dissection of head of Rita rita showing brain and olfactory nerve correlation with rosette.

1	CE	Cerebellum
2	Ey	Eye
4	OLF . LO	Olfactory lobe
3	OLF. BL	Olfactory bulb
5	OLF. NE	Olfactory nerve
6	OLF.RE	Olfactory rosette
8	OP. LO	Optic lobe
7	OP. NE	Optic nerve

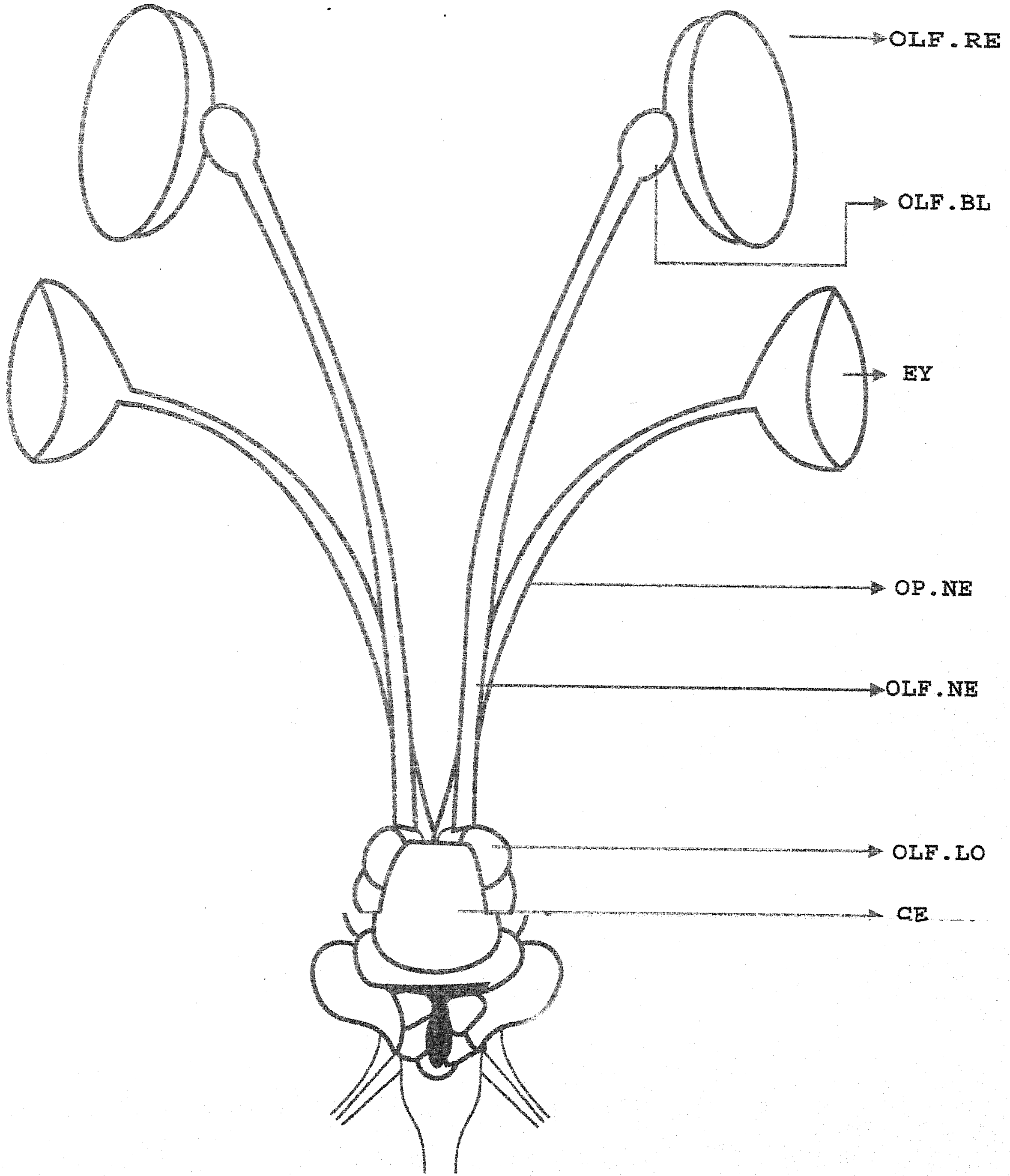


PLATE 3

HISTOLOGICAL OBSERVATION OF Rita rita

In Rita rita the olfactory organ consist of olfactory chamber on the dorsal surface of the head, close to the mouth and away from the eye orbit. These chambers are ventilated outside by a pair of openings, which are termed as anterior(ANT.NAS.TUBE) and posterior nasal openings (POST.NAS.OP).Both the openings are placed at the distance of 7mm from each other, demarcating two extremities of the olfactory chamber. The anterior nasal opening (POST. NAS.OP) is spherical, while the posterior nasal opening (POST.NAS.OP) is oval shaped which is covered by a collar shaped fold of skin called nasal flap. The flap extends anteriorly upward forming a short nasal barbel (NAS.BAR, PL 1).

Both the elongated olfactory chambers accommodates the rosette (RE)on the dorsolateral surface of the head. The rosette is(RE) found lying almost parallel to the antero posterior axis of the body and has a concave dorsal surface. The ventro lateral accessory nasal sacs (VEN. LAT. ACC. NAS.SAC) is found present in Rita rita compensating its bottom dwelling habit and habitat. This sac is well

developed and acts as an additional device to allow water for more time to olfactory surface maintaining continuos unidirectional flow of water current. It helps in holding up some foreign bodies and other available particles .

The bean shaped olfactory rosette(RE) in the olfactory chamber, throws out number of laterally flattened folds or lamellae(LAM). They are found attached on either side of a median thickening of the olfactory floor called raphe (RPH, PL 2 , 4 , 5, 7) , which is present in the middle of a rosette (RE)dividing it into two equal halves. The lamellae (LAM) are perpendicular to the raphe (RPH) and their number depends upon the size of the fish. The lamellae are attached ventrally to the floor of the olfactory chamber while they are free on their dorsal surface maintaining inter lamellar spaces(INT.LAM.SP).

The distal end (DIS.Z) of each lamellae (LAM) becomes constricted and reaches up to the extremity forming a narrow marginal area of the rosette(RE, PL 4). This demarks lamellae into wider central area and narrow peripheral area. The anterior lamellae are of moderate size, while the posterior one exhibits enormous

Plate – 4 Horizontal section of rosette of Rita rita showing median raphe and the attachment of lamellae on both sides. Lamellar zonal distinction and wall of olfactory chamber is clearly exhibited.

Plate – 5 Vertical section of rosette of Rita rita depicting lamellar attachment and submucosal composition of raphe cells can easily be distinguished as eosin and haematoxylin stain is clear.

BCZ	Basal cell zone
BC	Basal cell
CI.SC	Ciliated supporting cell
CON.TIS.FIB	Connective tissue fibers
DISZ	Distal zone
INT.LAM.SP	Inter lamellar space
MIDZ	Mid zone
MSA	Mucosa
NMN.FIB	Nonmedullated nerve fiber
PIG	Pigment
PROZ	Proximal zone
PN	Primary neurons
RPH	Raphe
SCZ	Supporing zone
SMSA	Submucosal
W.OLF.CH	Wall of olfactory chamber.

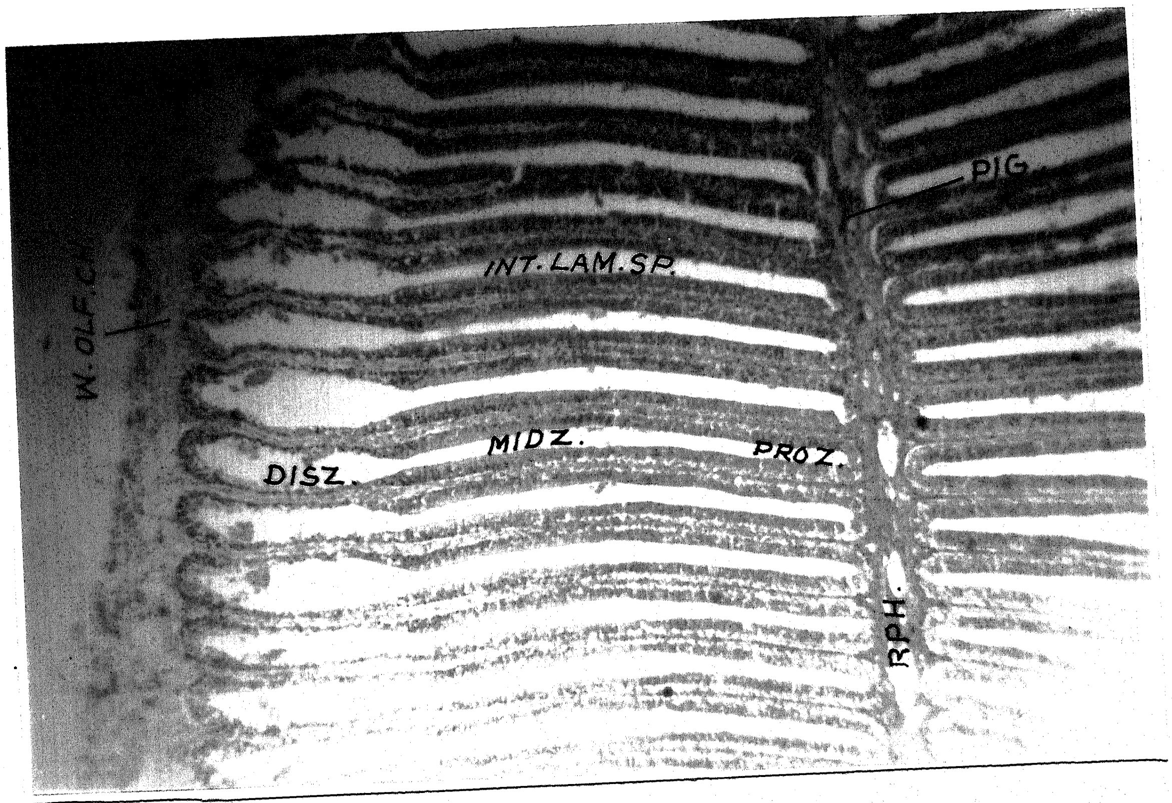


PLATE - 4

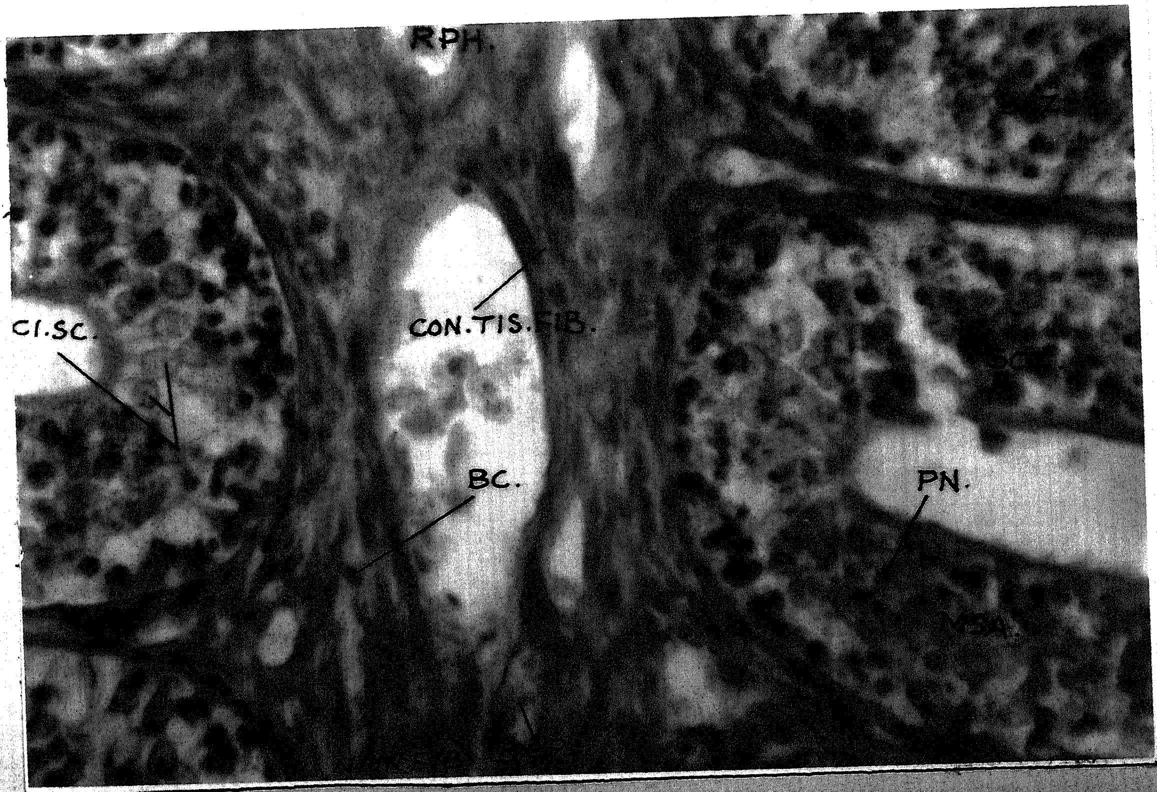


PLATE - 5

Plate – 6 Vertical section of rosette of Rita rita passing through posterior lamellar group showing different type of lamellae and their bending, curving, elongation, swelling, crupts of variable shapes and sizes depicting histoecological feature. Magnification x 100

Plate – 7 Vertical section of posterior group of rosette of Rita rita showing median bifurcation and other, histoecological formations. The eosin and haematoxylin stain is clear and demarcating different zones. Magnification x 100

BAND	Bending
CRY	Crupts
CUR	Curving
DISZ	Distal zone
ELON	Elongation
HIN.LAM	Hinder lamellae
INT.LAM.SP	Inter lamellar space
MSA	Mucosa
MID. BI	Middle bifurcation
MINL	Minor lamellae
MID.LAM	Middle lamellae
MID.Z	Middle zone
PROZ	Posterior zone
RPH	Raphe
SWE	Swelling
SMSA	Submucosa

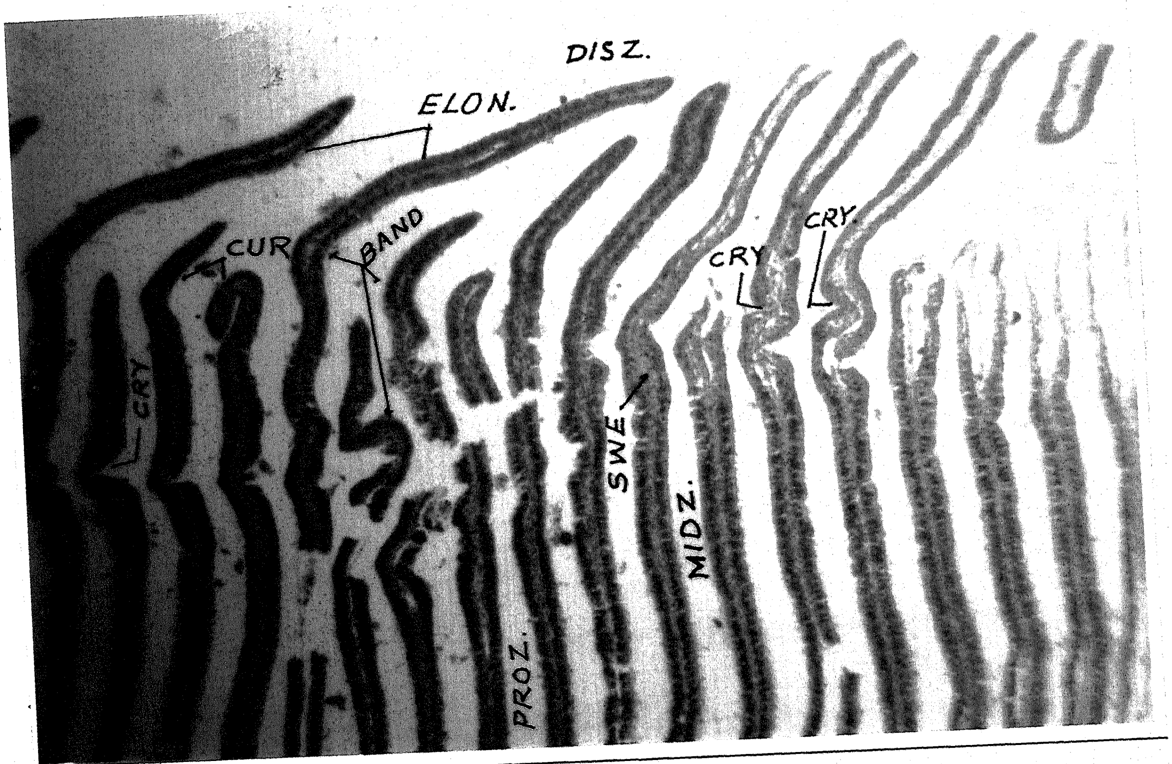


PLATE - 6

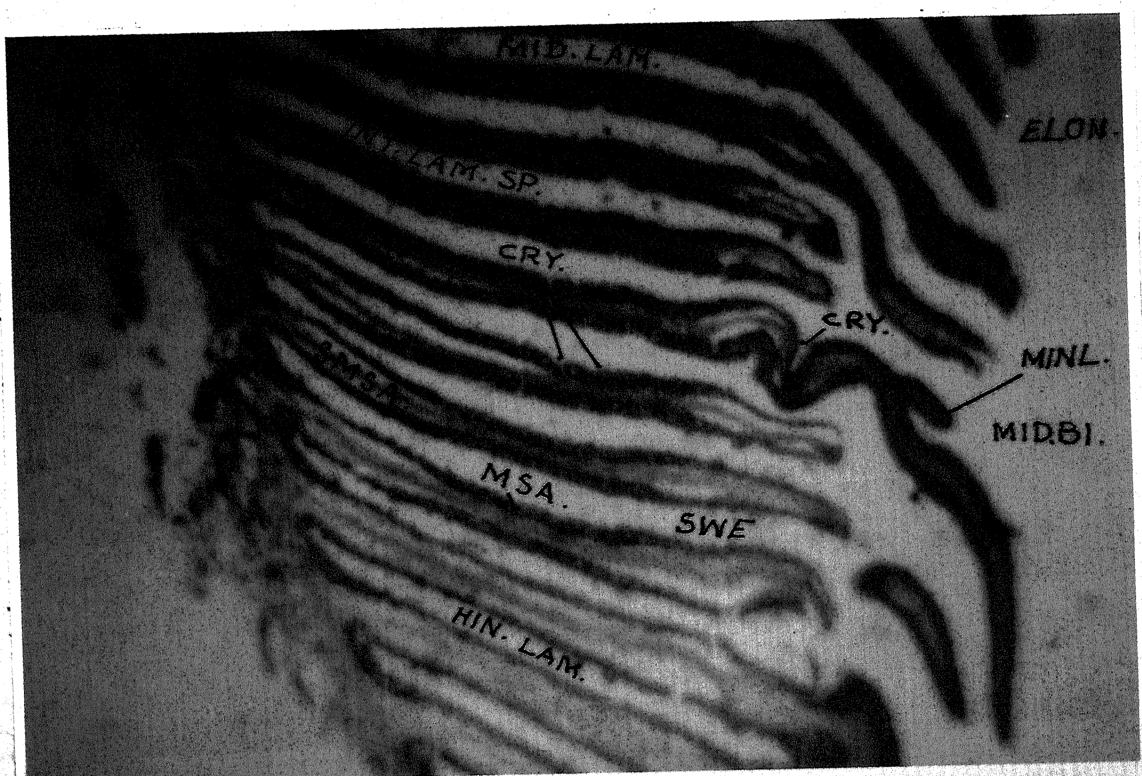


PLATE - 7

elongation(ELON),curving (CUR), detachment, swelling (SWE) indicating old and worn out group of lamellae(LAM, PL 6,7,12).In such groups there are micro formation of varied type causing enhancement of sensory surface area.

In Rita rita the rosette (RE) is pedunculated, supplied with nervous contents by olfactory nerve(OLF.NE), which extends from the olfactory bulb (OLF.BL) to the olfactory rosette(OLF. RE) . The olfactory bulbs(OLF.BL) are situated close to the posterior surface of the rosette(RE). They are large, well developed receiving the nerve fibers from each lamellae(LAM). The olfactory bulbs(OLF.BL) are anteriorly broad and becomes narrow posteriorly forming the olfactory tract(PL 3).

The olfactory lamellae can be demarcated into ; submucosa (SMSA) or central core and mucosa (MSA , PL 7 , 15, 23). The former is an extension of the tissues underlying the ventral wall of the olfactory chamber(W. OLF.CH), which on either side is lined by the cellular components of the olfactory epithelium called mucosa (MSA).The mucosa(MSA) is composed of pseudo stratified columnar and ciliated epithelium, which is abundantly

supplied with supporting cells (SC), receptors cells(RC) , basal cell(BC) and goblet cells (GC). In some lamellae abnormal swelling (SWE) of mucosa has also been noticed at distal end(DISZ, PL 6 , 7) . The mucosa(MSA) and submucosa (SMSA) are separated by a partition of basement membrane(BM, PL 10 , 25). The peripheral surface of the lamellae(LAM) is showing number of morphogenetic activities created by the bursting of goblet cells (GC) followed by flow of basal cells(BC) in the empty spaces left by mucus discharge .This is resulting in the different shapes of hillock elevation(ELE) , bifurcation(BI) , buds formation (BUD) ,depression(DEP) and detachment (PL 6, 7 , 12, 13 , 28) . Besides these microformations the crupts (CRY) are predominantly observed in this mucosal zone of Rita rita, which are of variable shapes and sizes lying at different level along with cellular composition (PL 6 , 21, 26,27,29,30). They may be exposed(CRY) and unexposed (UNCRY) on lamellar surface, accommodating large number of neurons, which sends their axon (AX) to folium olfactorium (FI. OL) and dendrite (DN) towards inter lamellar space (INT.LAM.SP, PL 8 ,9,23,24) for reception. This is so designed to fight with ecological encounters prevailing in particular medium. The bifurcations (BI) in lamella is also

Plate – 8 Vertical section of rosette of Rita rita showing group of . lamellae along with minor Lamella and unexposed crupt formed by the fusion of mucosa of mother and minor lamella. Sub mucosal division is indicated by arrow. Magnification x 100

Plate – 9 Vertical section of rosette of Rita rita showing basal minor lamella and bifurcation in which submucosa is sending its branch indicated by arrow. Section is showing dominant eosln stain Maginfication x400

BCP	Blood capillaries
CON.TIS.FIB	Connective tissue fibers
DISZ	Distal zone
INT.LAM.SP	Inter lamellar space
MSA	Mucosa
MINL	Minor lamella
MIDZ	Middle zone
PROZ	Proximal zone
RPH	Raphe
SMSA	Submucosa
UN.CRY	Unexposed crupts

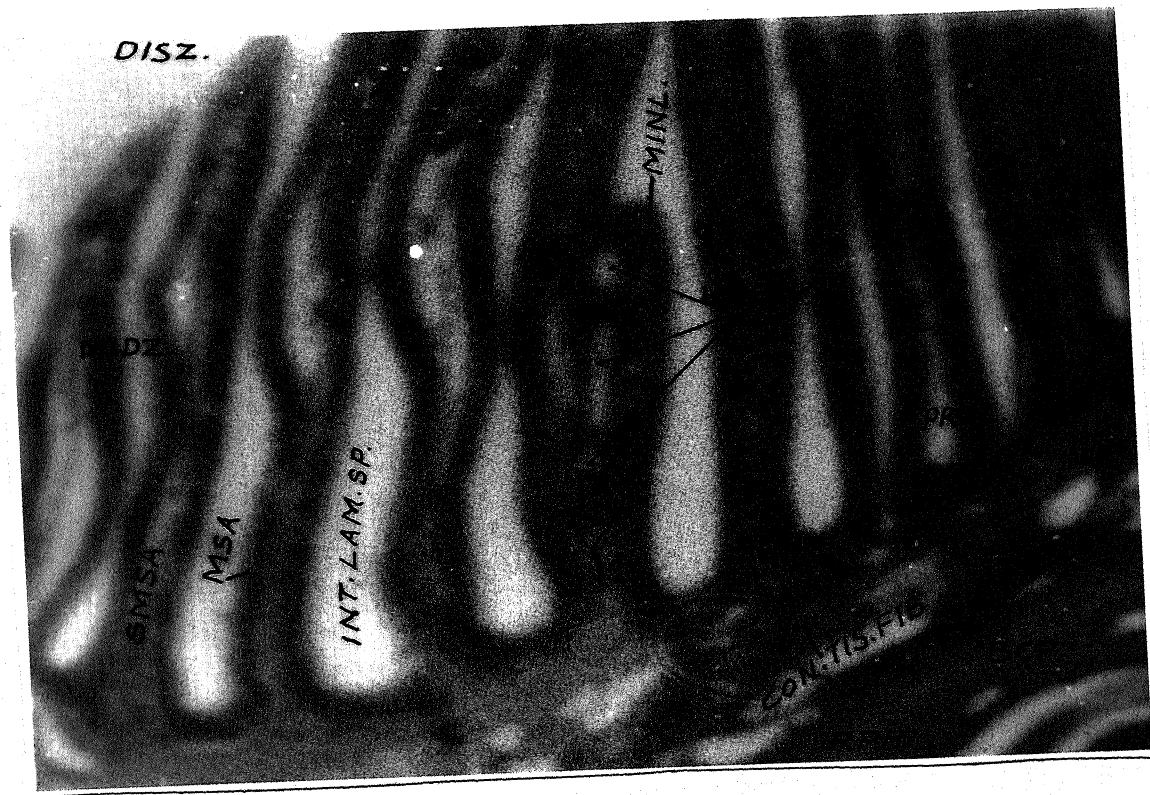


PLATE - 8

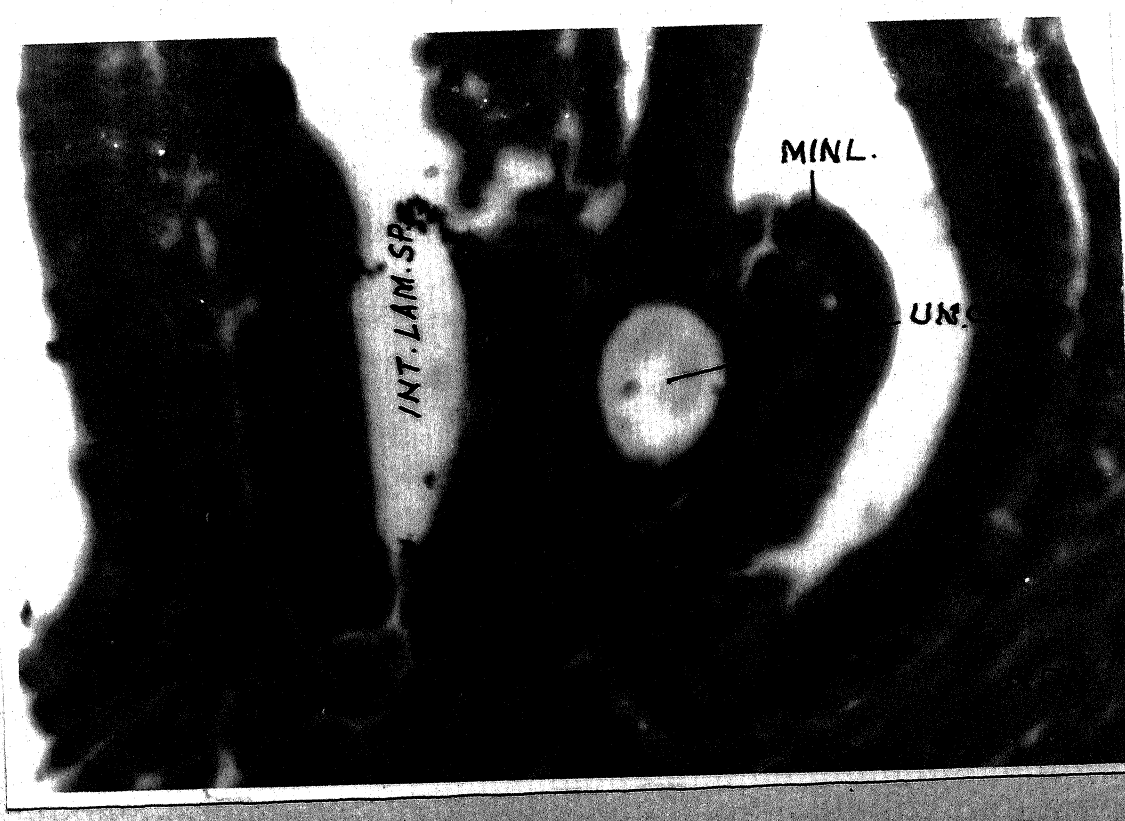


PLATE - 9

Plate – 10 Transverse section of lamella of Rita rita, showing median bifurcation resulting in minor lamellae which is a histoecological formation. Submucosal and other cellular composition branching is clearly seen as eosin and haematoxylin stain is equal magnification x 400.

Plate-11 Transverse section of lamellae of Rita rita showing terminal bifurcation in the form of minor lamella along with bifurcation in submucosa. Formation increasing the olfactory surface area. Magnification x 100.

BM	Basement membrane
FLOL	Folium olfactorium
FIB	Fiber
GC	Goblet cell
MSA	Mucosa
MINL	Minor lamella
NCLSC	Non ciliated supporting cells
PN	Primary neurons
RR	Rod shaped receptor cells
SMSA	Submucosa
TER.BI	Terminal bifurcation

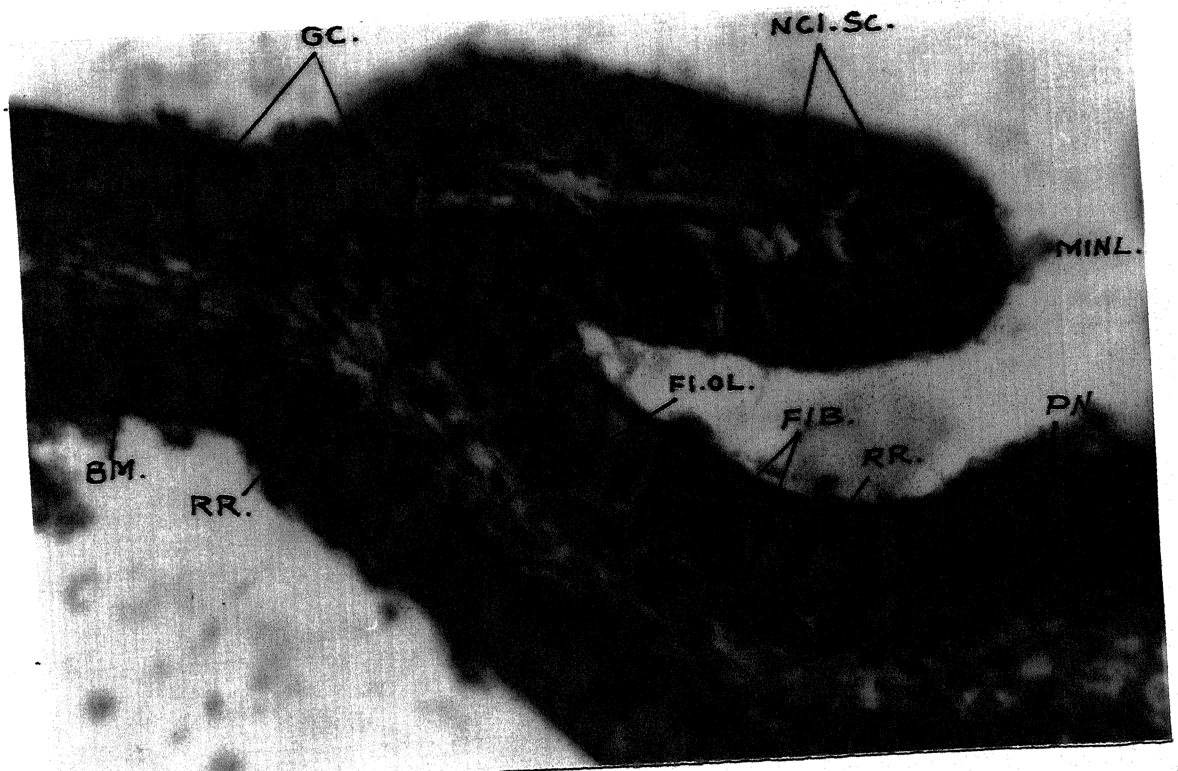


PLATE - 10

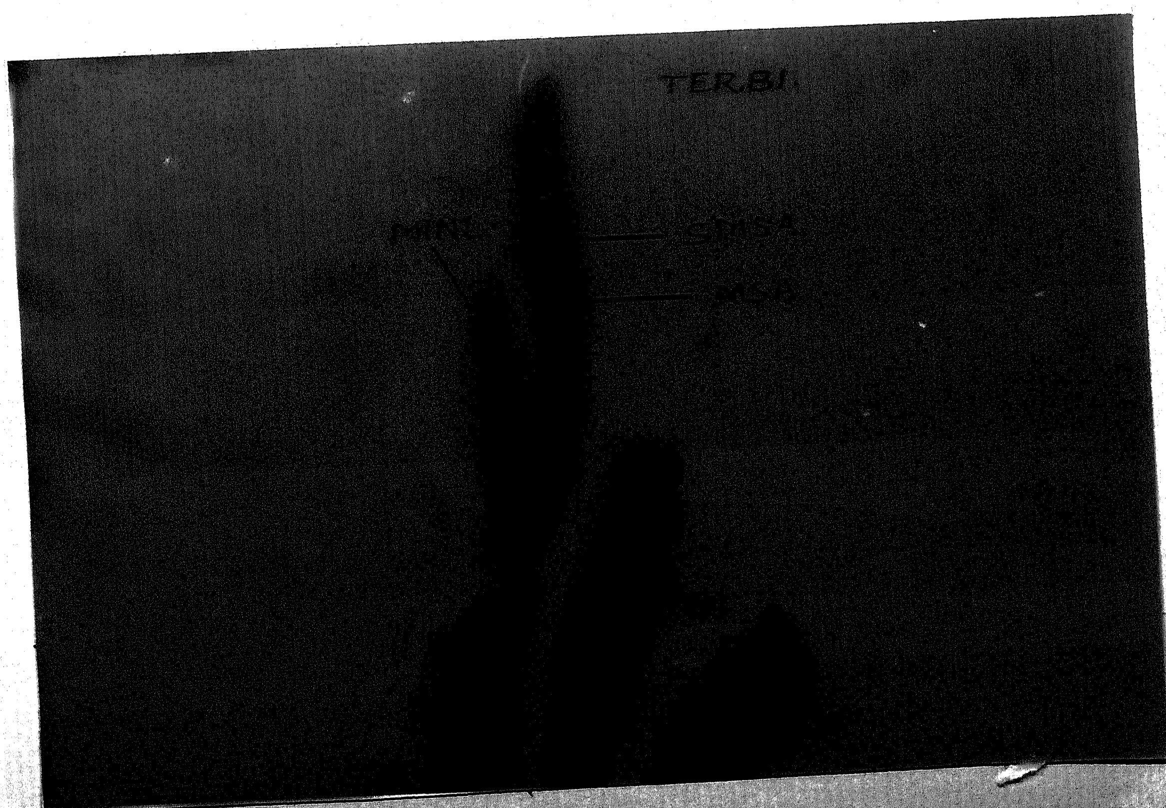


PLATE - 11

seen basely, medially and terminally in some specified lamellae (PL9,10,11). In such formations submucosa (SMSA) and mucosa (MSA) sends their independent offshoot supplying total submucosal and mucosal contents in these division and ultimately giving rise to minor lamella (MINL,PL 9,10,11,24). The mucosal area of minor lamella(MINL)becomes fused with mother lamella (MLAM) and give rise to unexposed crupts (UNCRY) of variables shapes and sizes(PL 8 , 23, 24).The olfactory epithelium of middle zone of lamellae(LAM) in Rita rita is interrupted in the form of depression, flask, funnel tubular and rounded vacuole like formation due to the bursting of goblet cells(GC) , while in the distal ends curving(CUR) is noticed turning down the terminal and of lamella in "U-shaped" structure(PL 6,21,25,27,29.30,31). The formation of "Cell ball" (C.BALL) is also observed which are arranged against the distal tip. These cell balls(C.BALL) contain all the contents of olfactory epithelium and it may also assumed that they may merged with some recipient lamellae (REC.LAM) mixed with former along its total contents(PL 12,14). In Rita rita bud (BUD) is found originating from the lateral surface of the distal end (DISZ) and contain all the contents of olfactory epithelium. It finally detaches from the mother

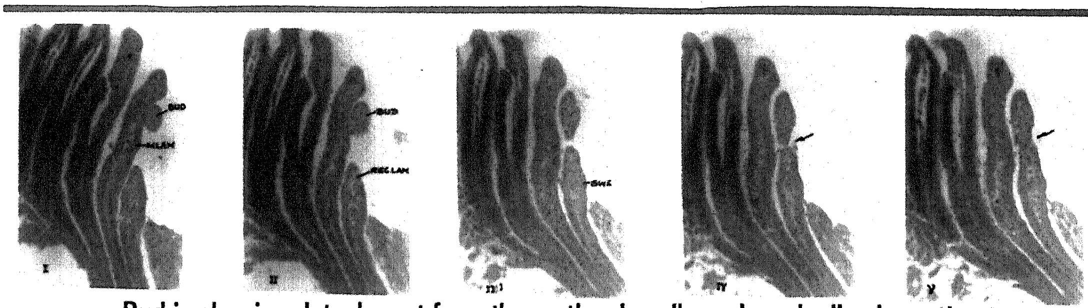
lamella (M.LAM) and attaches with adjacent lamella. In this process the recipient lamella and bud elongates gradually to join each other and ultimately the latter becomes fixed on the former(PL 12,13). All these morphogenetic activities aids in substituting lamellar surface and also to increase receptory area enabling the fish to cope up with diverse ecological conditions and also to with stand dominantly as a live fish in prevailing condition .

From histological point of view all the lamellae(LAM) of the rosette (RE)can be divided into three groups initial, median and hinder lamellae. The lamellae of these group show great variation in their cellular composition. The initial lamellae have compact cellular organization. The epithelial cellular lining are well built, giving the impression of youngest lamellae of the rosette, while submucosa(SMSA) is comparatively narrow having rich blood, connective tissue and cellular supply(PL 17,33,36) . The peripheral surface of initial lamellae is richly supplied with microformations.

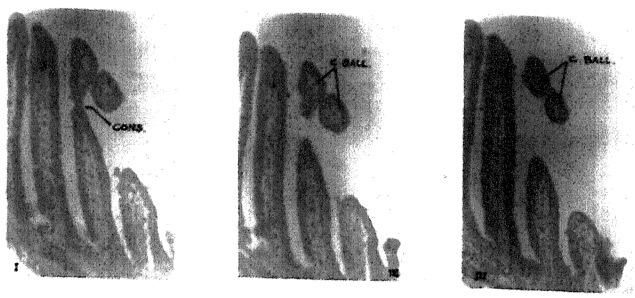
The middle lamellae have elongated body with distal end lined by indifferent epithelium and is richly supplied with large flask shaped mucous secretary goblet cells(GC).

Plate – 12 The bud is showing detachment from the mother lamella and gradually elongating to join distal end of recipient lamella in first row. The arrow is indicating union, while in second row discharge of cell ball by gradual constriction, is displayed showing histo ecological features.

BUD	Bud
C.BALL	Cell ball
CONS	Constriction
DE.LAM	Distal lamella
M.LAM	Mother lamella
RECI.LAM	Recipient lamella
RPH	Raphe



Bud is showing detachment from the mother lamella and gradually elongating to join distal end of recipient lamella.



The distal end of the lamella discharging "cell ball" by gradual constriction of under lying region .

PLATE - 12

The submucosa (SMSA)is well built in middle and distal region, but detaches from the basement membrane(BM) in an irregular manner in the proximal region of the lamellae(PL 8, 10,15,25,26). The distal end (DISZ)of these lamellae bears different microformations in form of bifurcation(BI), cell ball(C.BALL) and curving(CUR) of tips, which can be termed as histoecological modifications. The hinder ones are old and worn out set of lamellae(LAM) with enormously enlarged mucosa(MSA).It has fragment of blood capillaries (BCP) and loose collagen connective tissues(CON.TIS.FIB). These lamellae are composed of nonciliated supporting cells(NCI.SC.) and mucus secreting goblet cells(GC, PL 19).

In the initial lamellae the swelling of mucosa(MSA) is noticed which ultimately curves the lamellae in different shapes, increasing the surface area. The bending of lamellar tips is observed in middle lamellae. In these bendings different types of depressions(DEP) and hillock elevations (ELE) are found due to the bursting of goblet cells(GC) and flow of basal cells(BC,PL 21, 25, 26, 27, 28, 29, 30,31). At these points the cilia of receptor cells protrude out in inter lamellar spaces and this histological change help fishes to live in diverse habitat by making its surface area more

Plate-13 Vertical section of terminal zone of Rita rita showing bud formation laterally which is a histo ecological activity. The eosin mount is dominant while haematoxylin stain is dull. Magnificationx400.

Plate –14 Vertical section of lamella of Rita rita . showing arrangement of cell ball at terminal zone . Section is showing more eosin stain. Magnification x400.

BC	Basal cell
BUD	Bud
BCP	Blood capillaries
BCZ	Basal zone
C.BALL	Cell ball
INT.LAM.SP	Inter lamellar space
LYM	Lymph
MSA	Mucosa
MGC	Migratory goblet cells.
MLAM	Minor lamella
NCI.SC	Nonciliated supporting cells
REC.LAM	Recipient lamellae
SMSA	Submucosa

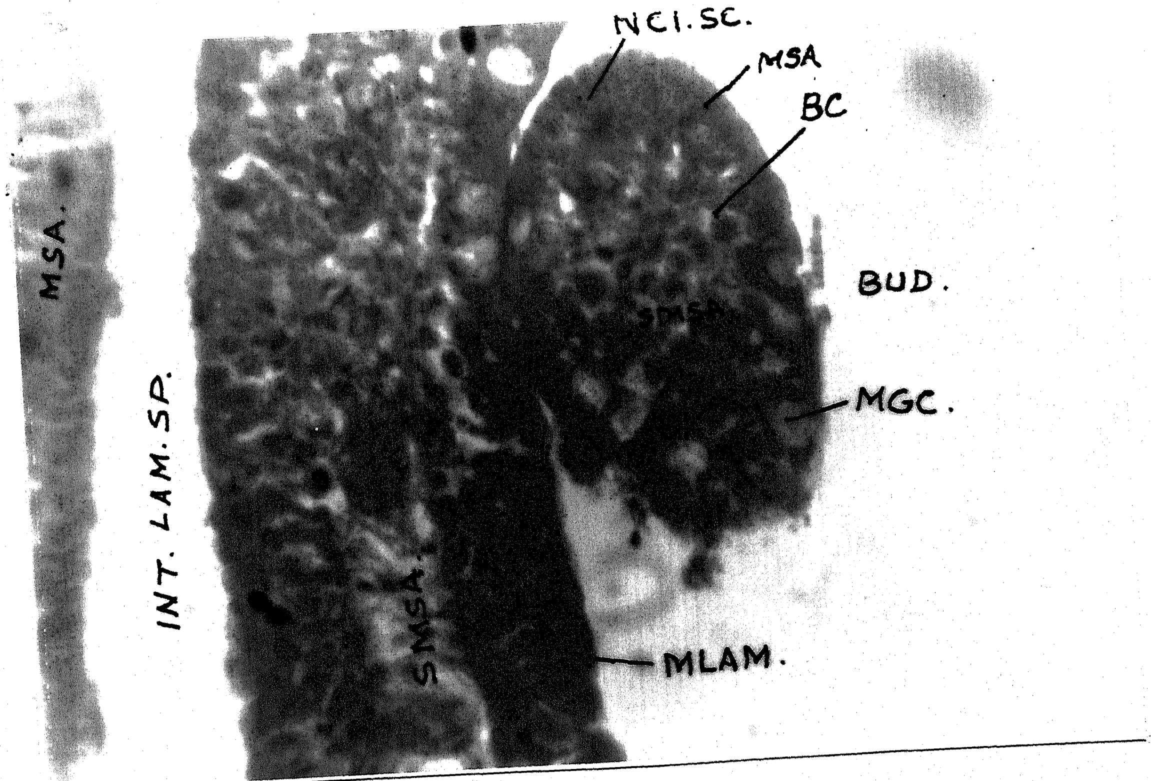


PLATE - 13

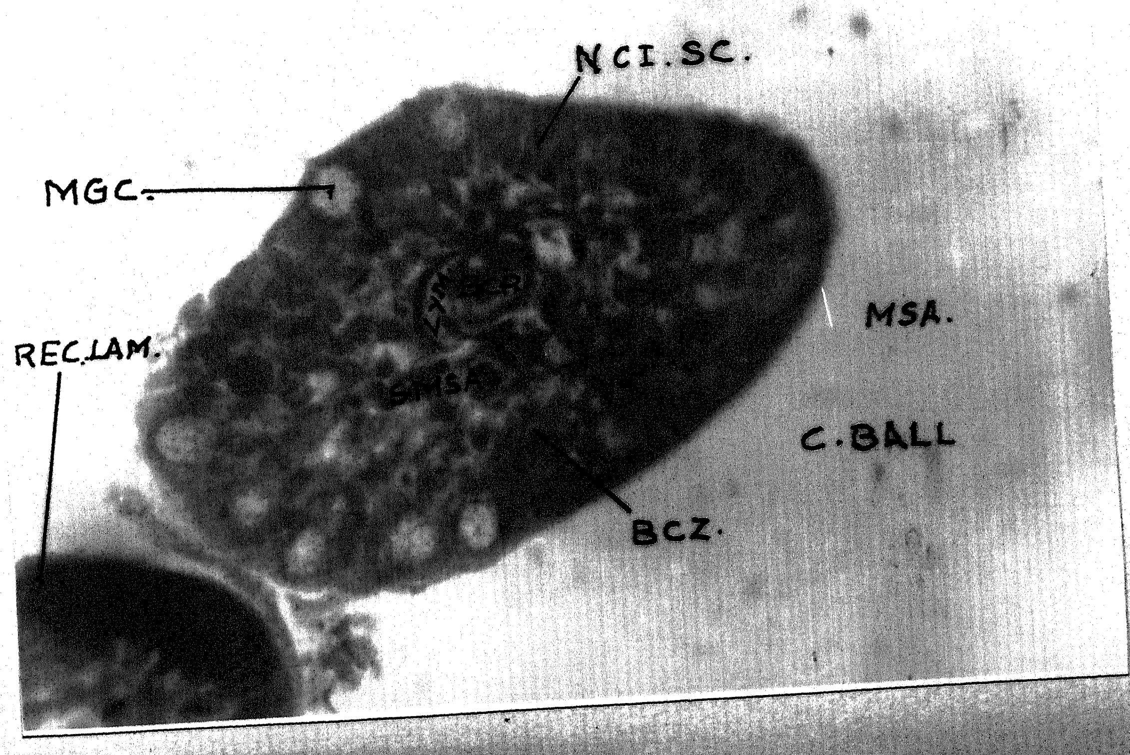


PLATE - 14

F

Plate-15 Vertical section of joining of cell ball with recepient lamella after getting detach from mother lamella in <u>Rita</u> <u>rita</u> junctional morphogeetic activity is clearly visible section is showing eosin stain dominantly Magnification x 400.

Pl

Plate –16 Horizontal section of rosette of <u>Rita</u> <u>rita</u> showing supporting turger in addition to raphe because of enormous presences of lamellae in the rosette. to fasilated prompt exposure to aquatic circulatory current Magnification x 100.

C.BALL	Cell ball
FU.LAM	Fusion of lamellae
GC	Goblet cell
INT.LAM.SP	Inter lamellar space
LYM	Lymph
MSA	Mucosa
MUC	Mucus
MGC	Migratory goblet cell
REC.LAM	Recipient lamella
SMSA	Submucosa
TUR	Turger
W.OLF.CH	Wall of olfactory chamber

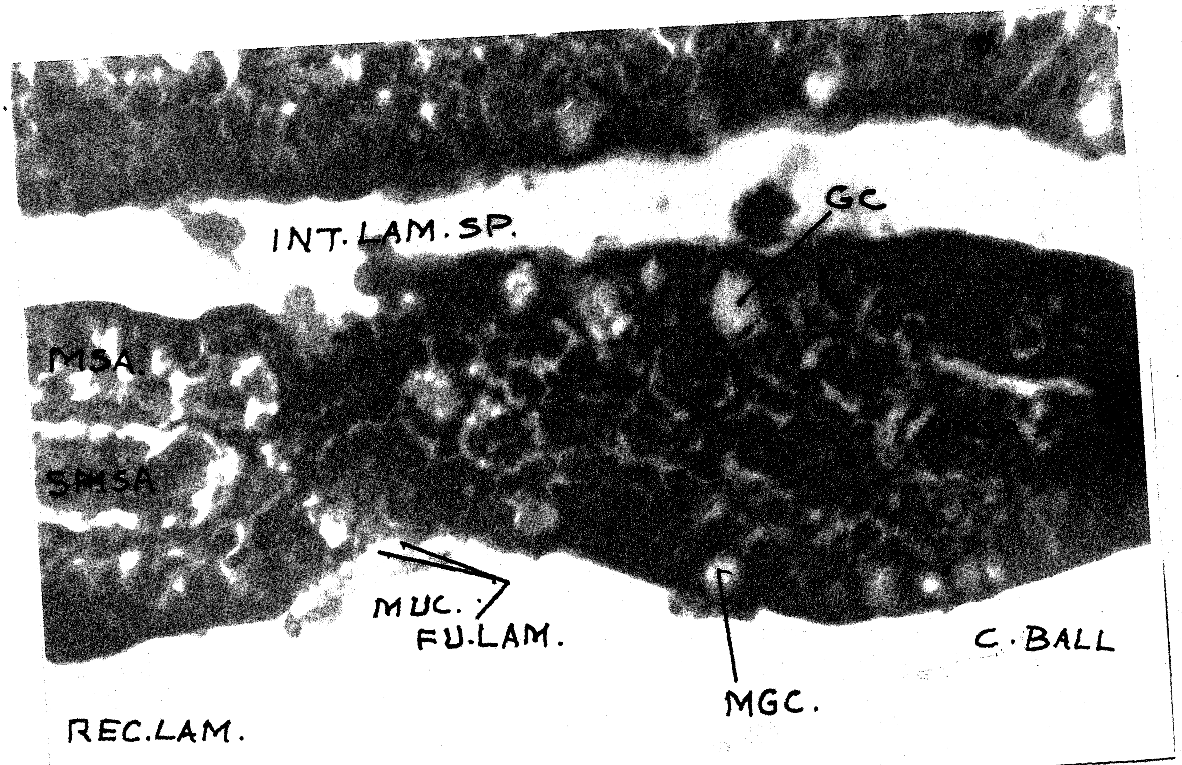


PLATE - 15

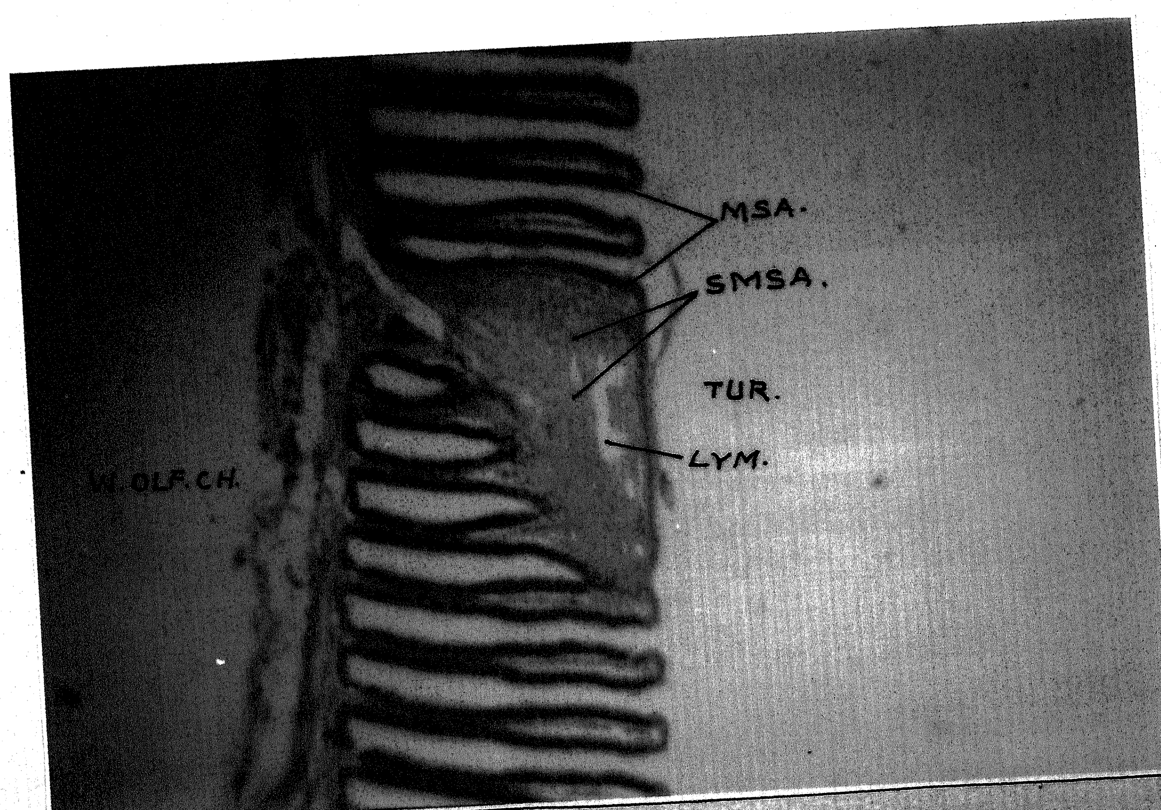


PLATE - 16

sensitive . Some times the point at which lamellae(LAM) bends grows deeper and finally detaches that portion from the main lamellae giving rise to cell balls(C.BALL). These are found arranged parallel to the distal end of the lamellae. This may be assumed that they might be supplying their contents as cellular supplement to the recipient ones. In the middle lamellae due to the bursting of goblet cells (GC) the crupts (CRY) are formed, through which cilia of receptor cells projects out giving an impression of olfactory bud. The elongation (ELON) of lamellar tip in initial and middle lamellae is histoecological modification, which makes the lamellae more sensitive to olfactory receptions.

On the basis of distribution of cells, the lamellae of Rita rita can be divided into following zones:

Distal zone: This zone is composed of nonciliated supporting cells (NCI.SC), which is richly supplied with mucous cells (GC).In this zone elongations(ELON), curving (CUR) and bending (BAND) of lamellae occurs, which increases its surface area(PL 20).

Middle zone: In this zone ciliated supporing cells (CI.SC) and goblet cells(GC) are found alongwith large number of elevation (ELE) and depression(DEP) due to the bursting of goblet cells as a result of which periphery becomes wavy. (PL 21)

Proximal zone : This zone extends on either side of the raphe (RPH) up to the middle region of the olfactory lamellae. This regions is richly supplied with supporting cells and receptor cells but is devoid of mucous secretary goblet cells . (PL 22)

In the olfactory epithelium of Rita rita following type of cells are identified: supporting cells or sustantecular cell (SC), the receptor cells (RC), the goblet cells(GC) and the basal cells(BC). The arrangement of cellular components in the mucosa of a lamellae from inner to outer margin is found in the following series. The mucosa(MSA) and submucosa (SMSA) is separated by a layer of basement membrane(BM), above which lies the basal cells(BC). These basal cells are the innermost cells with rounded or irregular nucleus. The basal cells are followed by receptor cells and then by the sustantecular cells. The goblet cells are confined in the distal zone(DISZ) of the lamellae intermingled with supporting

I Plate-17 Vertical section of initial lamellae of Rita rita showing mucosal and submucosal cellular composition eosin and haematoxylin is demonstrating cellular content clearly. Magnification x 400

P Plate –18 Vertical section of middle lamella of Rita rita showing, deepening and elevation on its mucosal surface. Upward arrow indicating dendritic and downward axonal extension. Lamella depicting histoecological feature. Magnification x 400.

BCZ	Basal cell zone
BC	Basal cell
CI.SC	Ciliated supporting cell
DEP	Deepening
ELE	Elevation
GC.TH	Goblet cell theca
INT.LAM.SP	Inter lamellar space
MSA	Mucosa
MUC	Mucus
NCI.SC	Nonciliated supporting cells
PN	Primary neuron
RR	Rod shaped receptor cells
SMSA	Sub mucosa
SCZ	Supporting zone
SR	Spindle shaped receptors

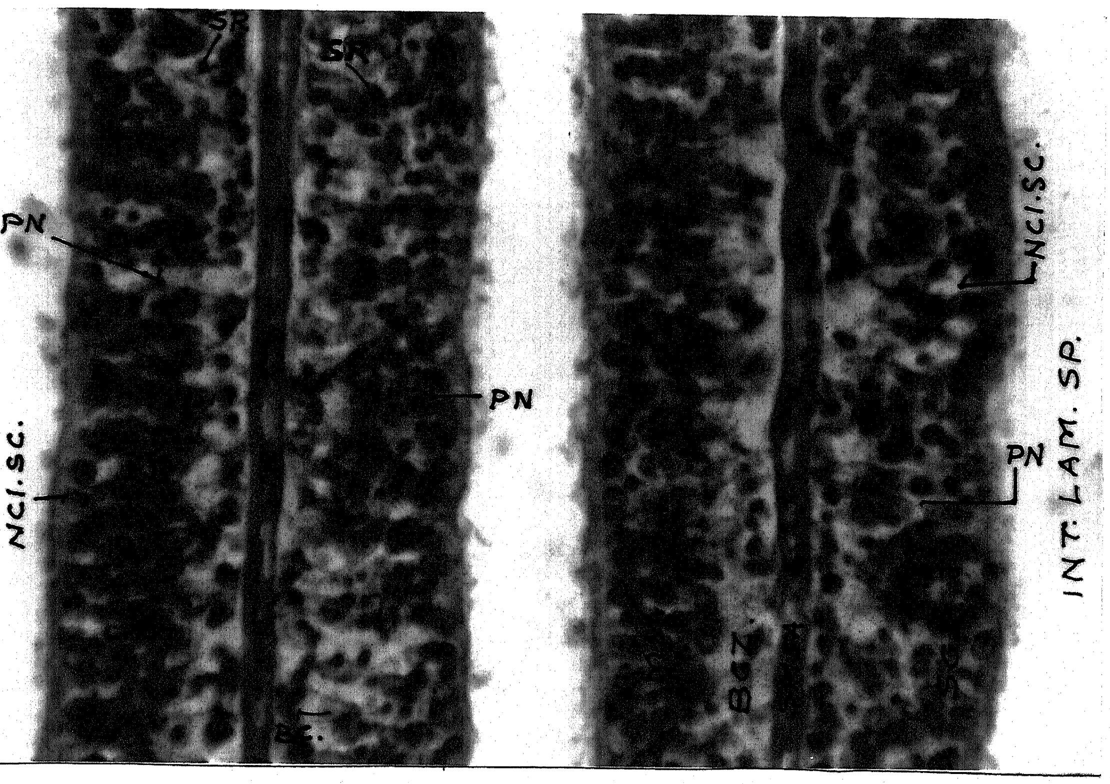


PLATE - 17

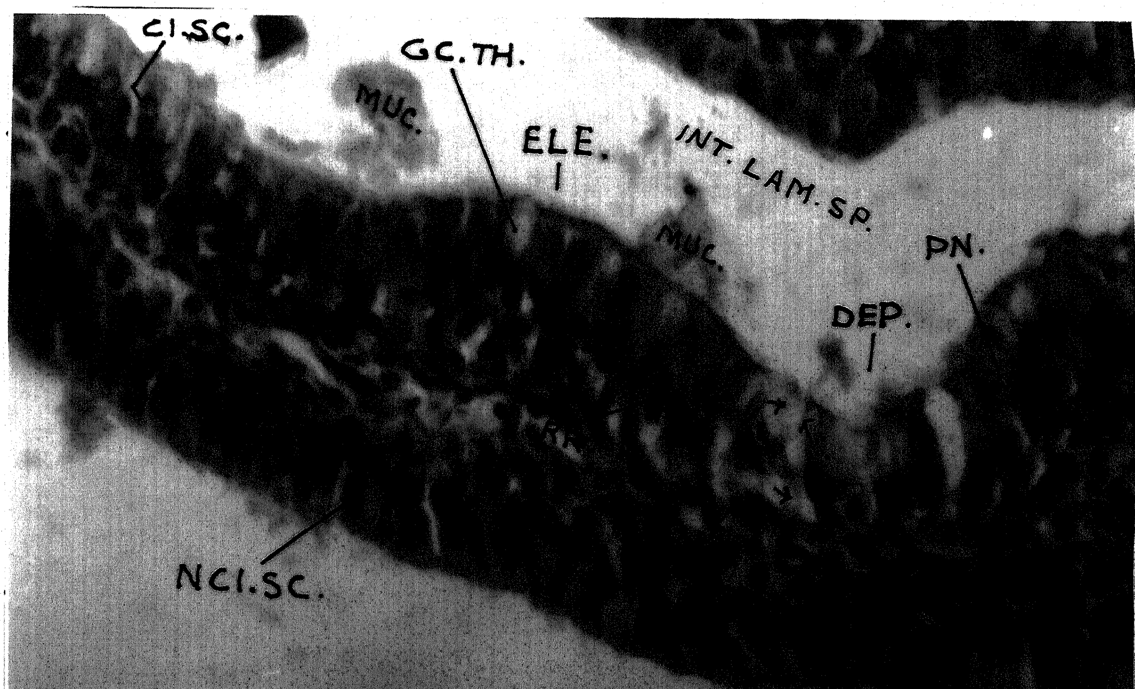


PLATE - 18

F Plate-19 Vertical section of hinder lamella of Rita rita showing enormous enlargement in submucosal zone and thining in mucosal zone displaying old and worn out lamellae with rarely distributed connective tissue fibers. Magnificationx400.

F Plate –20 Vertical section of distal zone of lamellae of Rita rita showing distal cellular composition in mucosal and submucosal zone with dominate distribution of goblet cell. Magnification x400.

BC	Basal cell
BM	Basement membrane
BCP	Blood capillaries
BCZ	Basal zones
BL	Blastema cell
CON.TIS.FIB	Connective tissue fibers
FIB	Fibroblast cell
GC	Goblet cell
GL.TH	Goblet cell theca
MSA.	Mucosa
NCI,SC	Nonciliated supporing cells
NUGC	nucleus of goblet cell
SCZ	Supporting cell zone
SMSA	Submucosa
SC	Supporting cell

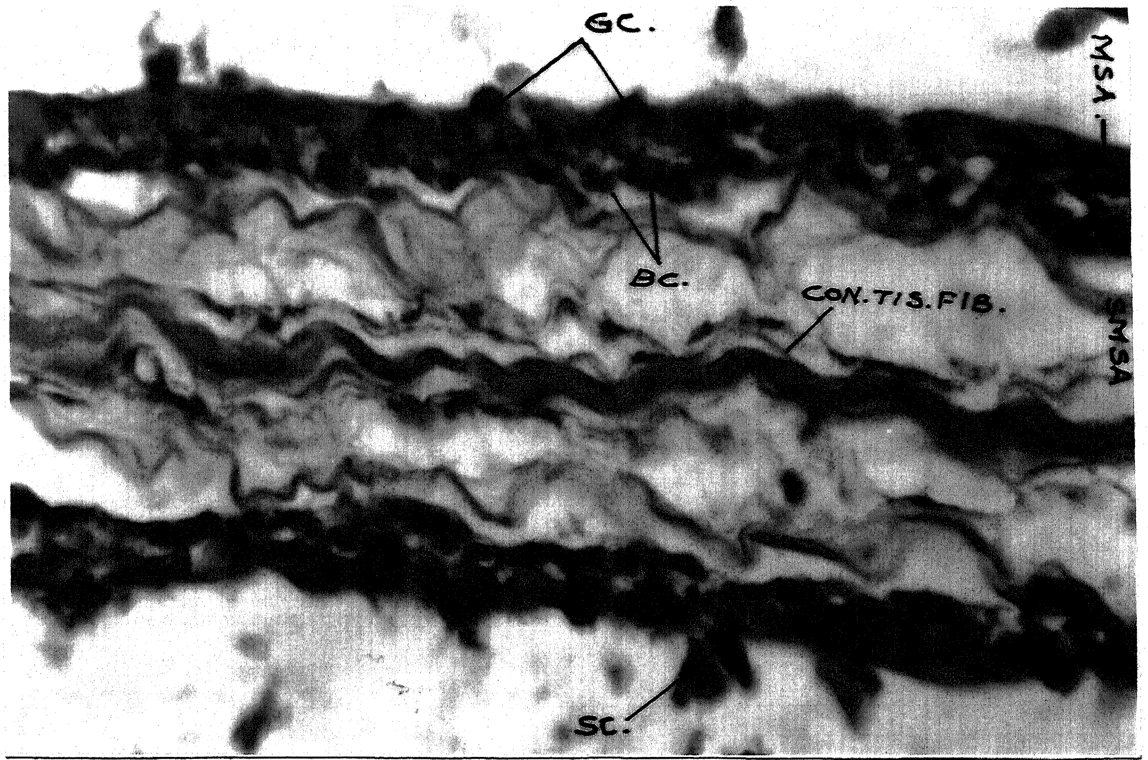


PLATE - 19

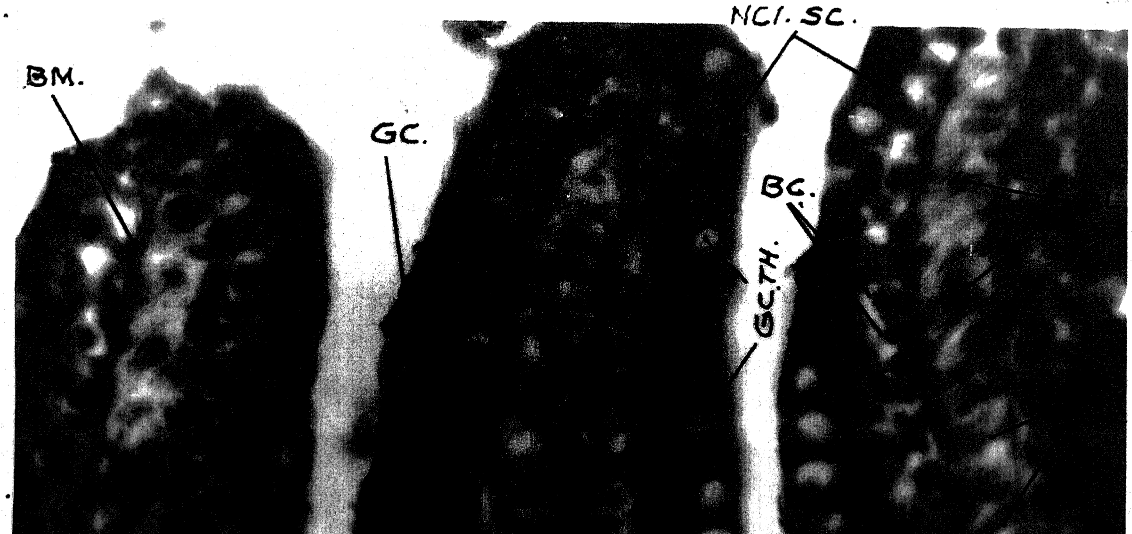


PLATE - 20

cells. The peripheral surface is found filled with the cilia(CI) of the respective cells. The submucosa and raphe is richly supplied with fibroblast(FIB), histocytes(HIS), basal cells(BC) and blastema cells(BL).The blastema cells forms the macrophages which contributes in creating protective system within submucosa for fighting with germs, bacteria and others foreign particles ,that get enter in olfactory chamber along with water current(PL 34,35).

The supporting cells or sustantecular cells

Whole of the peripheral surface of the lamellae is lined by supporting cells(SC), lying adjacent to or intervening the goblet cells(GC). The sustantecular cells are columnar or cuboidal cells arranged in mucosa of the olfactory epithelium. On the basis of their structure these cells are of two types: non ciliated supporting cells(NCI.SC) and ciliated supporting cells(CI.SC) .

The non ciliated supporting cells (NCI.SC) are confined in the distal region (DISZ)of initial and middle lamellae while the epithelium of hinder one is mainly made up of these cells. The nonciliated supporting cells (NCI.SC)

I Plate-21 Vertical section of specific middle zone of lamellae of Rita rita showing dominant mucosal activity and displaying funnel shaped crupts, dense ciliation, different type of receptor cells along with mucosal and submucosal cellular composition lamella is showing histoecological modification by increasing its surface area. Magnification x400

F Plate –22 Vertical section of proximal zone of Rita rita lamella, showing ciliation and normal mucosal and submucosal composition along with different types of receptors. Arrow indicating downward and upward extension of axon and dendrite respectively. Magnification x 400

BC	Basal cell
BL	Blastema cell
BCZ	Basal cell zone
CI.SC	Ciliated supporting cell
CRY	Crypts
FIB	Fibroblast
GC	Goblet cell
HIS	Histocytes
MSA	Mucosa
NCI.SC	Nonciliated supporting cell
NU.CI.SC	Nucleus of ciliated supporting cell
O.CI	Olfactory cilia
PN	Primary neurons
RR	Rod shaped receptor cells
SMSA	Submucosa
SR	Spindle shaped receptor cells
SCZ	Supporting zone

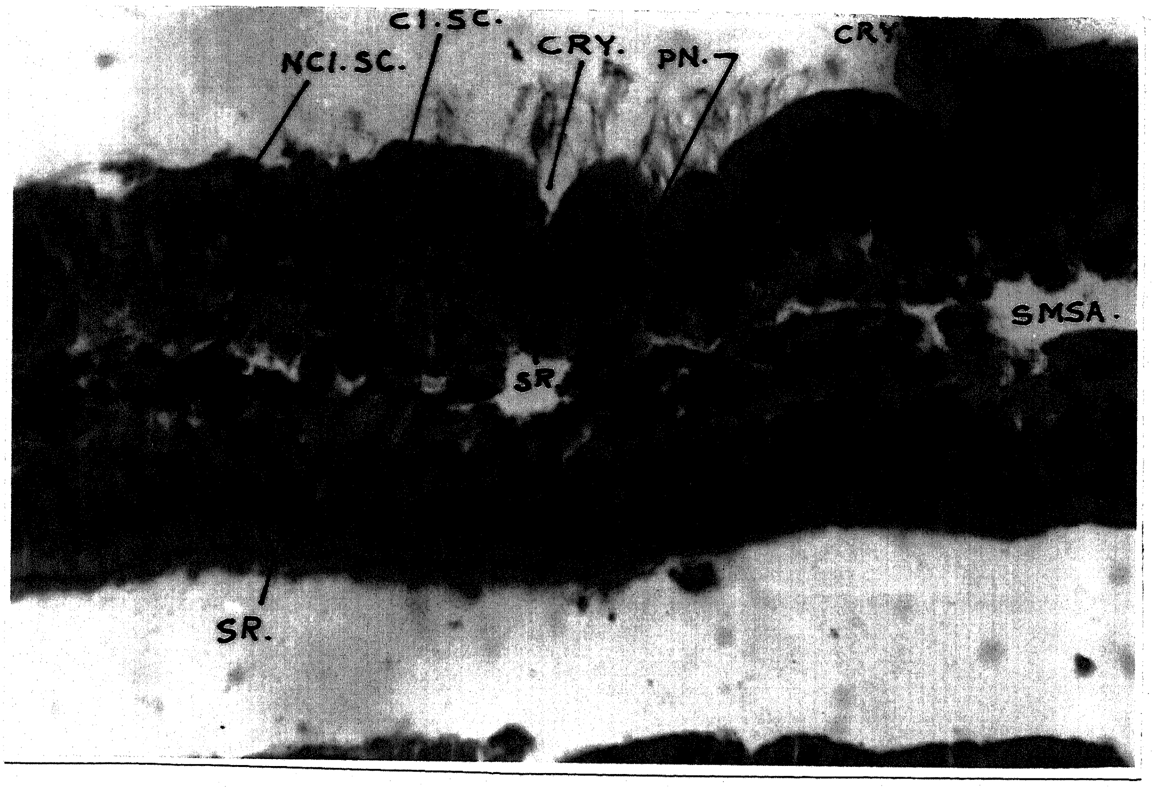


PLATE - 21

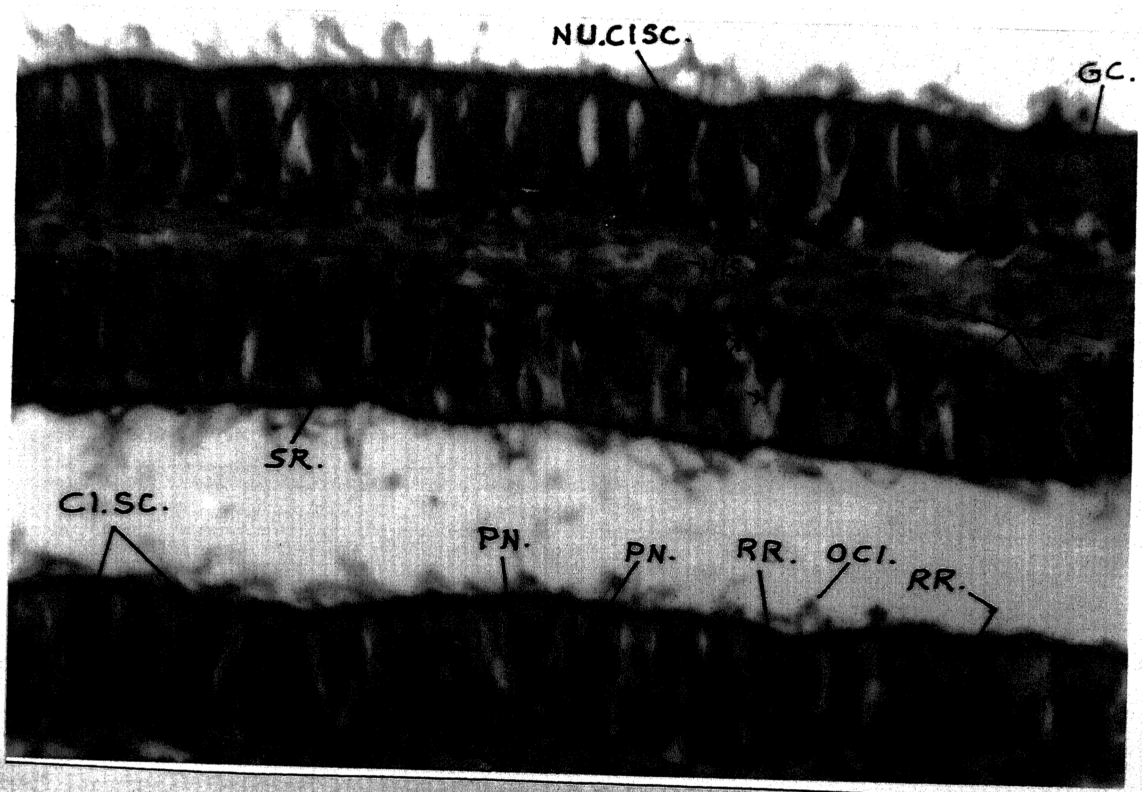


PLATE - 22

are short, columnar and nonciliated provided with oval nucleus(NU). The chromatin material is dust like and uniformly distributed. The outer end of these cells is broad, short and terminates by expanded tip at the peripheral surface. The olfactory epithelium of hinder lamellae is mainly constituted of non ciliated cuboidal supporting cells(CUSC). These cells has short and broad distal limb with darkly staining rounded nucleus. The cuboidal supporting cells are compactly arranged along the peripheral surface of the mucosa (MSA)which provides insulation to the dendrites (DN)of the spindle shaped receptor cells (SR). The centrally placed nucleus is clearly visible(PL 17,19,21,25,30,32). The ciliated supporting cells(CI.SC) are columnar and confined in the proximal and middle region of the initial and middle lamellae, while the hinder lamellaes are devoid of these cells. The arrangement of these cells is very compact and no inter cellular spaces can be seen among them in the epithelium. The ciliated supporting cells(CI.SC) can be divided into two limbs on the basis of their contents: the proximal or inner limb and distal or outer limb. The former limb is short inconspicuous and extents up to the basement membrane(BM), while the latter limb is broad and elongated, extending up to the peripheral surface of the lamellae(LAM).

The distal end of the ciliated supporting cells bear a long cilia(CI), which projects into the interlamellar space(INT.LAM.SP), showing the unidirectional movement. These cells possess a spherical or oval nucleus(NU) in the proximal part of the inner limb. A centrally located nucleus is clearly visible and chromatin material is evenly distributed in karyoplasms. The nucleus of ciliated supporting cells takes the darker stain with haematoxylin. These cells are also present in crupts giving impressions of olfactory bud(PL 18,33,34,35,36).

The receptor cells:

The receptor cells(RC) are richly supplied throughout the olfactory epithelium of Rita rita irrespective of their restriction in any particular region of the lamellae. However their percentage is greater in crupts and middle region of the lamellae(LAM). The receptor cells are found situated among the ciliated(CI.SC) and nonciliated supporting cells(NCI.SC) and their concentration is notable. These cells are situated deep in the olfactory epithelium and send their elongated dendrites to the peripheral surface of the lamellae. The dendrites(DN) of the receptor cells is of filamentous nature

Plate-23 Vertical section of rosette of <u>Rita</u> <u>rita</u> passing through minor lamella depicting unexposed crupts, formed due to fusion of mucosal content of mother lamella and minor lamella. Submucosal contents are also clearly visible and eosin stain is dominant. Magnification x 400.

Plate –24 Vertical section of rosette of <u>Rita</u> <u>rita</u> passing through the zone showing division of submucosa to main and minor lamella other cellular composition is also exhibited clearly. Magnification x400

BM	Basement membrane
BCZ	Basal cell zone
INT.LAM.SP	Inter lamellar space
MSA	Mucosa
MINL	Minor lamella
NMN.FIB	Nonmedullated nerve fiber
SMSA	Submucosa
SCZ	Supporting zone
UNCRY	Unexposed crupts

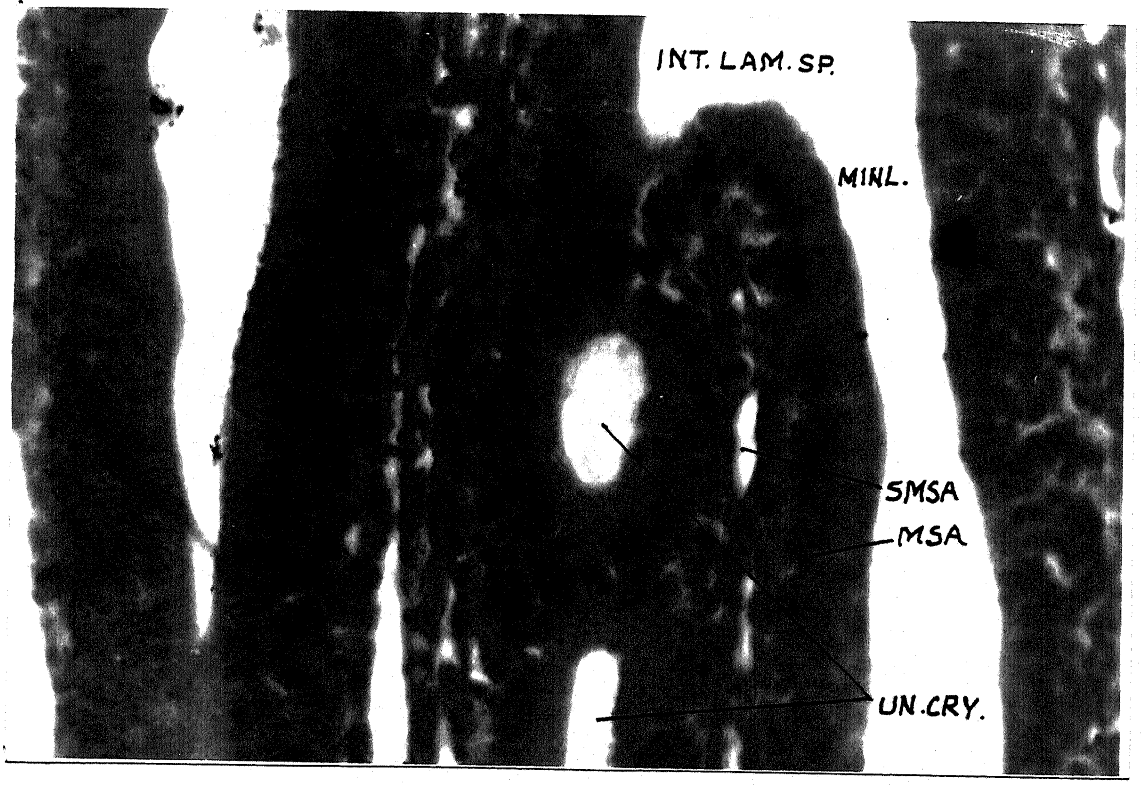


PLATE - 23

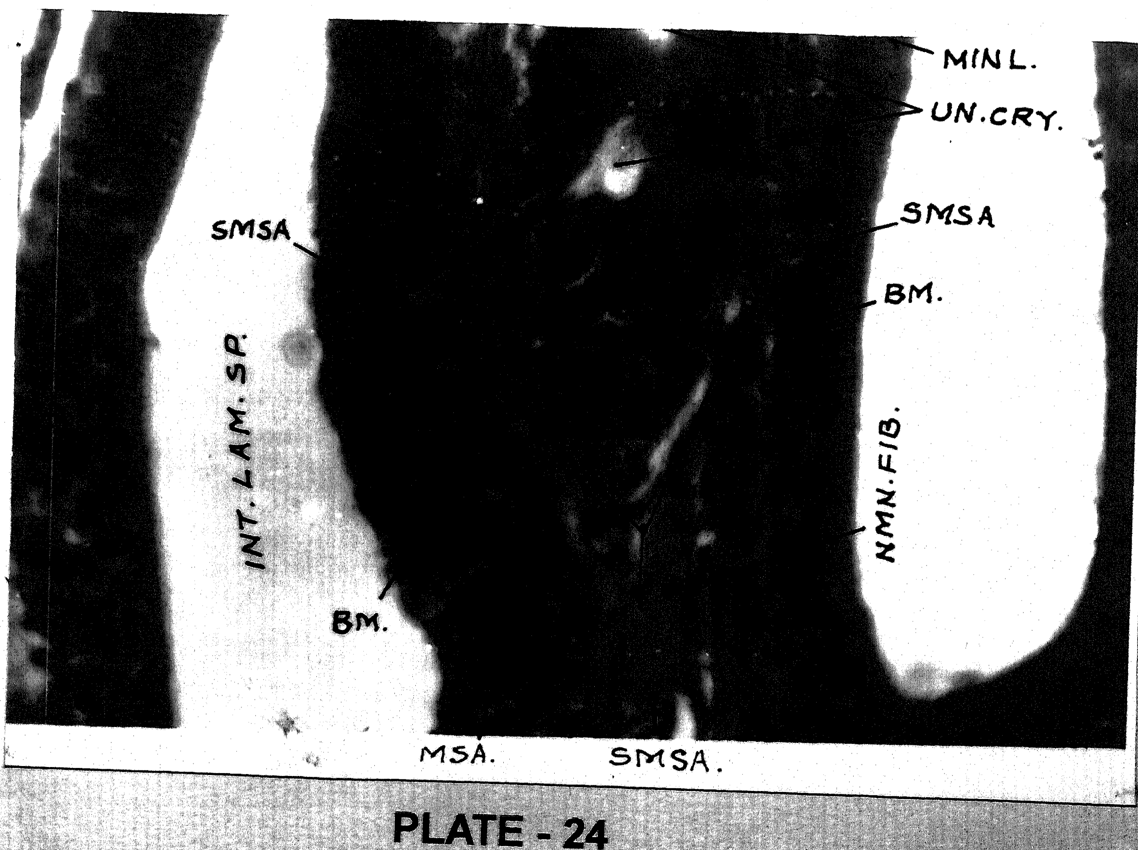


PLATE - 24

Plate-25 Vertical section of lamella of <u>Rita rita</u> showing terminal curving along with other cellular composition and receptors . The section is depicting histoecological feature. The arrows indicating dendrite and axon pathway of rod shaped receptor cells. Magnification x 400

Plate –26 Vertical section of distal end of middle lamella of <u>Rita rita</u> showing the histoecological activity more ciliation , crupts, bending, curving , elevation and total mucosal and submucosal composition. Magnification x 400

BC	Basal cell
BM	Basement membrane
CI	Cilia
CRY	Crupts
ELE	Elevation
FIB	Fibroblast cells
GC	Goblet cell
MSA	Mucosa
MGC	Migratory Goblet cells
NCI.SC	Nonciliated supporting cells
OCI	Olfactory cilia
RR	Rod shaped receptor cells
SMSA	Submucosa
SR	Spindle Shaped receptor cells

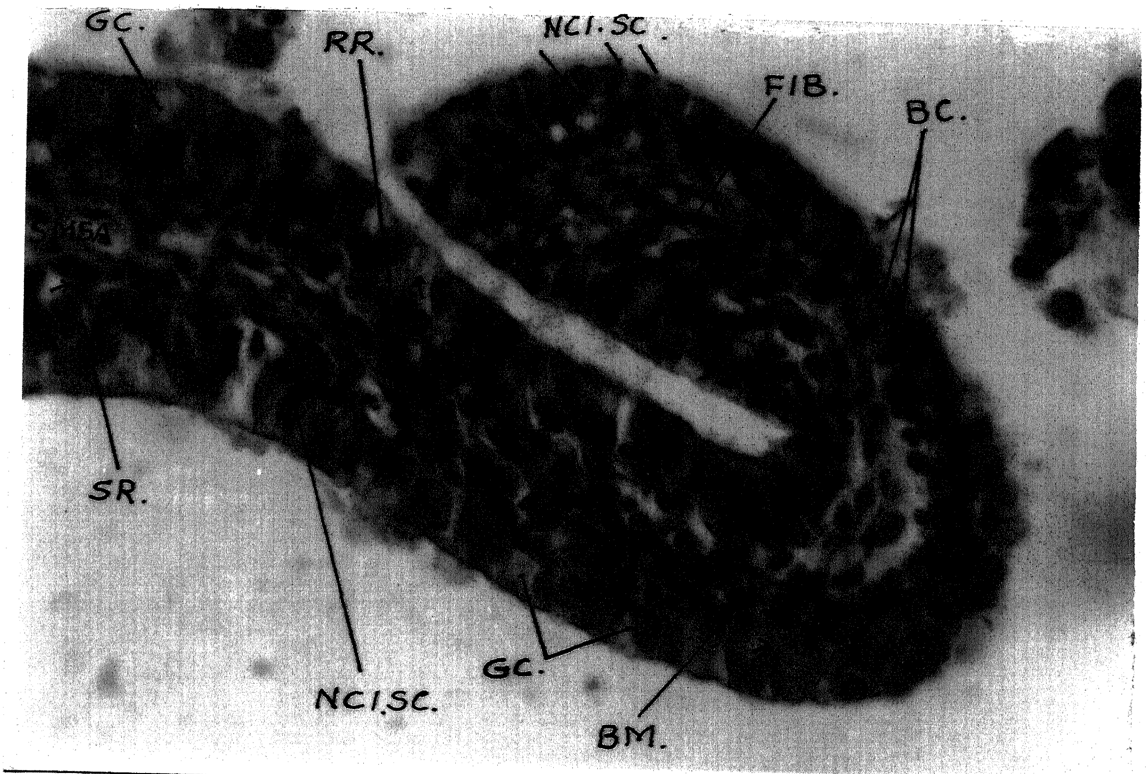


PLATE - 25

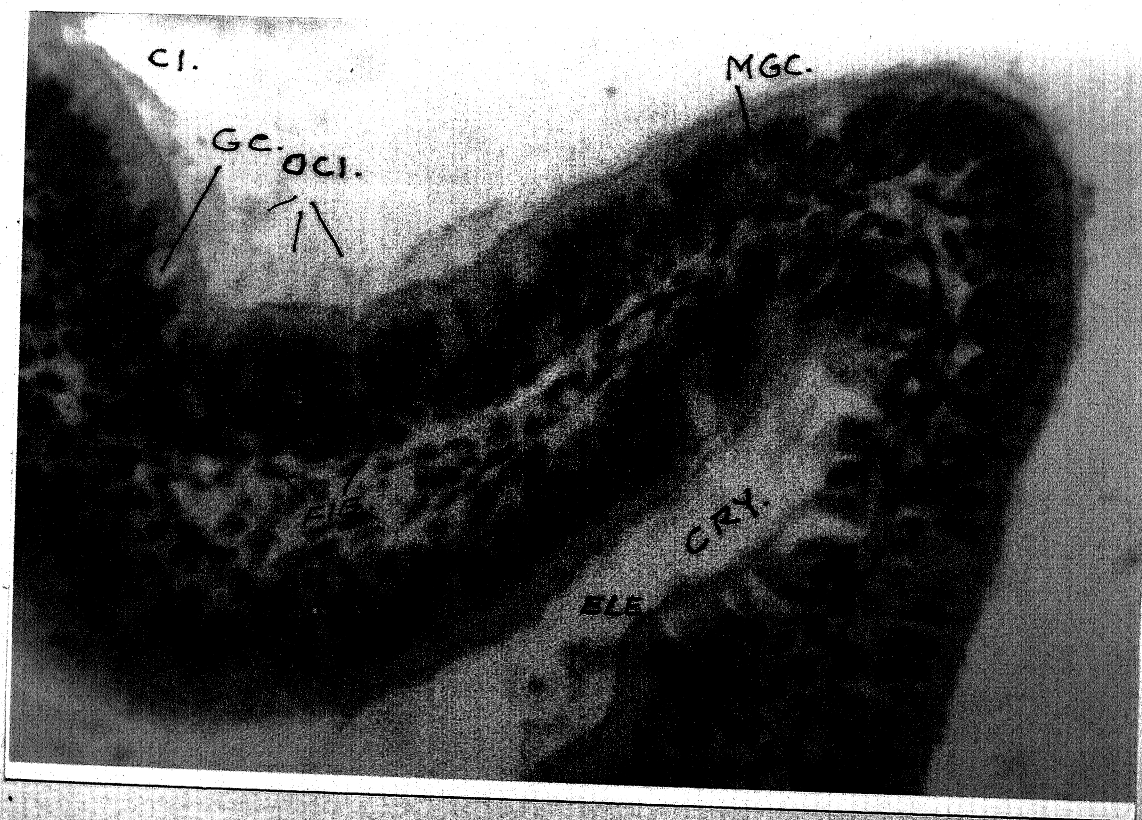


PLATE - 26

and can be easily identified from distal end of supporting cells. The olfactory cilia(OCI) of these receptor projects out from the distal tip and they are longer than the cilia of sustantecular cells. The axonal (AX)end of the receptor cells meet along the basement membrane(BM) and forms the folium olfactorium (FI.OL), which joins nonmedullated nerve fibers (NMN.FIB)running through the raphe(RPH, PL 18,22,27,30,32,36).

The receptor cells can be classified into three category on the basis of their structure:primary neuron(PN) rod shaped receptor cells(RR) and spindle shaped receptor cells(SR). The primary neuron are spherical receptor cells, which are abundant in crupts. These cells bear a rounded nucleus which sends its fibrillar dendrite to the peripheral surface. The dendrite is a darkly staining fiber. The primary neurons(PN) are found lying in the interruption caused by bursting of goblet cells in the form of crupts(CRY), hence they are found situated at periphery or close to the basement membrane(BM). The terminal dendritc end of these cell bears olfactory cilia(OCI) and remain in contact with water current passing through inter lamellar space(INT.LAM.SP). Due to the insignificant length the independent identity of the

axon (AX)cannot be traced out but in the 'U shaped' tip it can be easily traced out(PL 17,30,32,33,35,36).

The rod shaped receptor cells(RR) are found in initial and middle lamellae. These cells has a darkly staining narrow elongated nucleus and send almost equal size dendrite(DN) and axon (AX)to respective zones . Their dendrites(DN) are thick and rod shaped extending either in between the theca of goblet cells or transversing single or in groups through the empty theca of the goblet cells. The dendrite(DN) of these cells distally joins together and form expanded tip ,while the axon (AX)elongates and extends up to a basal zone(BCZ) where they join to form folium olfactorium (FI.OL, PL 18,25,33,34,35,36).

The spindle shaped receptor cells(SR) bear elongated or oval nucleus with long cilia. The axonal(AX) end is also considerably long and can be traced out in the olfactory epithelium. In the elevation(ELE) these cells cannot be observed among supporting cells, while in crupts and among marginal goblet cells they are significantly visible. The spindle shaped receptor cells (SR) establishes synaptic contact in between the dendrites(DN) of former and axon

(AX) of primary neurons (PN)generally in middle of mucosa. It is also observed that the primary neurons and spindle shaped receptors cells aggregates in crupts and the projection of their olfactory cilia (OCI) gives a shape of deeply embedded lotus shaped "olfactory bud" but on the peripheral surface of olfactory mucosa (PL 21,27,32,33,34,35,36).

The goblet cells:

In Rita rita the mucus secretary goblet cells(GC) are the dominating cellular component of the olfactory epithelium. In the proximal region of initial and middle lamellae goblet cells(GC) are rare in number but in distal region their exsistance is remarkable . The goblet cells are found confined in initial and middle lamellae but can also be encountered any where in hinder ones(PL 19,20).

In Rita rita the goblet cells(GC) are found arranged serially throughout the peripheral surface of the lamellae . A fully developed goblet cell bears an apical end filled with pale droplets of mucigen, while slender basal end contains compressed nucleus(NU.GC) and small amount of the deeply staining cytoplasm. The apical part of these cells has expanded cup , like structure called the theca (GC.TH),

Plate-27 Vertical section of distal end of middle lamellae showing exposed crupts with aggregation of primary neurons heavy, ciliation mucus secretory activity is also visible. Arrow indicating upward extension of dendrite to inter lamellar space. Magnificationx400

Plate –28 Vertical section of distal end of initial lamellae showing histoecological activity in the form of sharp deepening and different types of receptor and other cellular composition. Magnification x400.

BCZ	Basal zone
CRY	Crupts
DEP	Deepening
ELE	Elevation
GC	Goblet Cells
INT.LAM.SP	Inter lamellar space
MUC	Mucus
NCI.SC	Nonciliated supporting cell
MSA	Mucosa
PN	Primary neurons
RR	Rod shaped receptor cells
SCZ	Supporting zone
SMSA	Submucosa
SR	Spindle shaped receptor cells

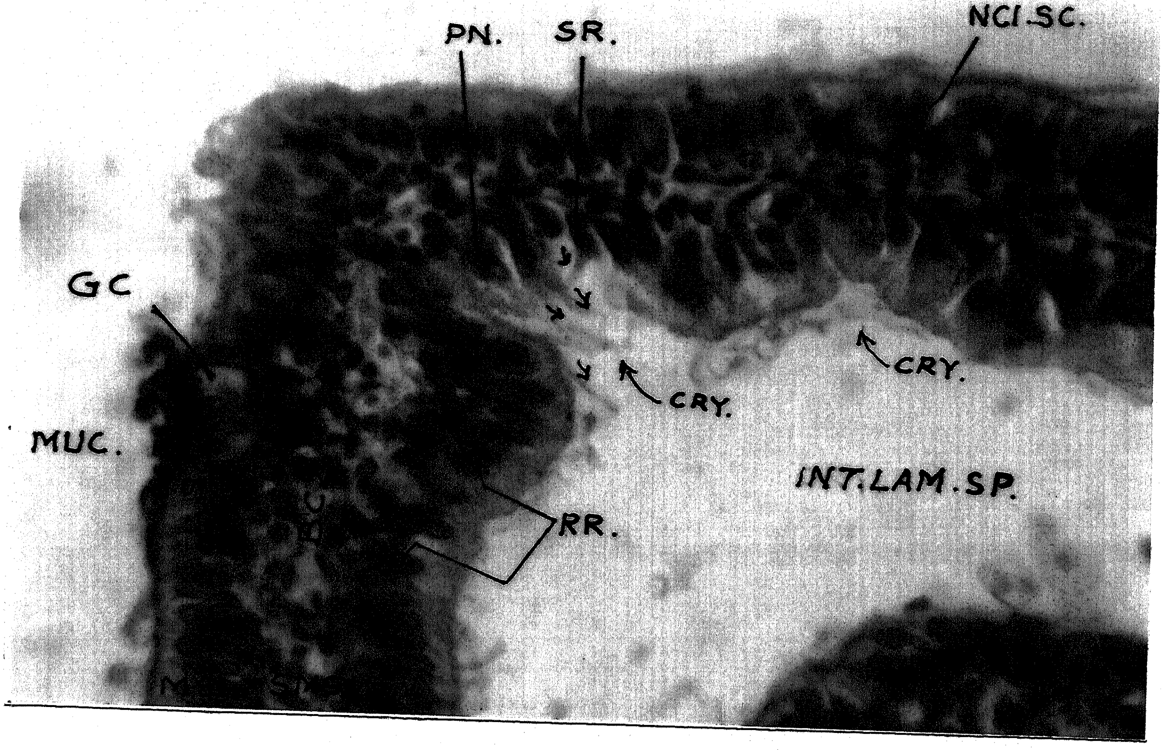


PLATE - 27

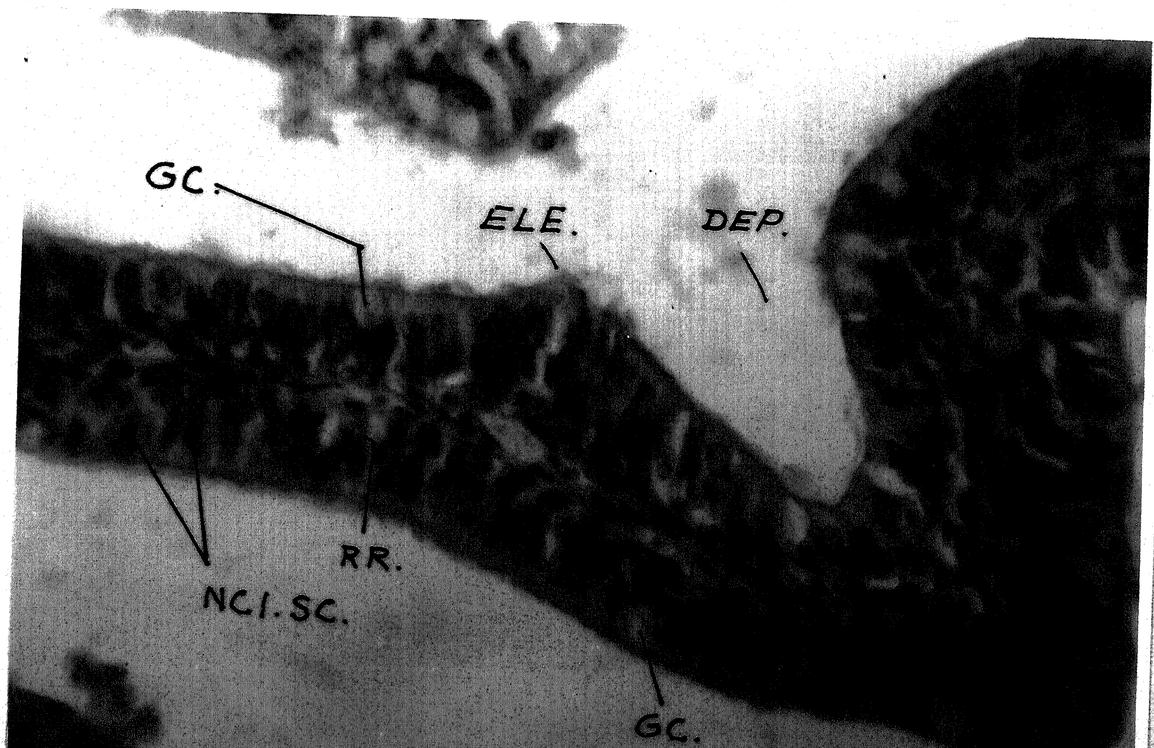


PLATE - 28

F

Plate-29 Vertical section of rosette of Rita rita showing morphogenetic activity on mucosal and submucosal surface forming histoecological crupts, elevation and other changes in different cellular composition. Pigmentation in submucosa is also visible . Magnification x400

F

Plate –30 Vertical section through lamella of Rita rita showing crupts on its both surface opening into inter lamellar space with dense aggregation of primary neurons. Blood capillaries is prominently visible supplying blood circulation to such histoecological formation . Magnification x 400

BCZ	Basal cell zone
BCP	Blood capillaries
CON.TIS.FIB	Connective tissue fibers
CRY	Crupts
ELE	Elevation
FIB	Fibers
GC	Goblet cell
MGC	Migratory goblet cell
MSA	Mucosa
NCI.SC	Non ciliated supporting cells
PN	Primary neurons
PIG	Pigment sheath
SR	Spindle shaped receptor cells
SCZ	Supporting zone
SMSA	Submucosa

which is filled with secretary droplets. The theca becomes empty after discharging the mucous content in the inter lamellar spaces(INT,LAM,SP). The inner part is stem like extending up to the basement membrane(BM). The nucleolus and chromatin material in nucleus is not visible due to the high degree compression(PL 13,14,18,20).

In Rita rita two types of goblet cells are found :

1. Marginal goblet cells and
2. Migratory goblet cells.

The marginal goblet cells(GC) are found at the periphery of the cell. These are large flask shaped cells formed by the transmission of the non ciliated supporting cells(NCI.SC). The nuclear and cytoplasmic contents are pushed in the form of triangular darkly staining mass situated proximally in the cell body. At some place the mucus(MUC) discharge is seen. The cilia of the rod shaped receptor cells(RR) are found either lying in between the theca of these cells or traverse through the empty theca (PL 15,18,20,26,27,28). The migratory goblet cell (MGC) originate from the muciperous basal cells(BC) and are found concentrated in the proximal or intervening region of the lamellae, adjacent

to the raphe. These cells have rounded structure with nucleus and has wandering tendency from deeper zone to peripheral zone of the olfactory epithelium(PL 13,14,15,20,32) . The newly formed migratory goblet cells (MGC)generally form groups and fuses in the form of complicated vacuole like structure, which gradually grows in size and ultimately burst on the peripheral surface of the lamellae, discharging its content in the inter lamellar space. This activity of these cells form crupts(CRY) which may be in form of depression, flask, funnel or tubular deepening. Crupts(CRY) may be of 3 types depending about, there existence in olfactory epithelium:the peripheral crupts, the middle crupts and basal crupts. From these crupts peripheral crupts are exposed crupts (CRY, PL 21,26,27,30,31)) , while middle and basal crupts are unexposed crupts (UNCRY)as they are deeply situated.

In Rita rita olfactory epithelium is affected greatly , due to the migratory process of these cells as it causes the displacement of basal cells(BC). The flow of basal cells (BC) take place in any direction and leads to the formation of hillock elevation(ELE), straight projections(ELON) or bifurcation(BI) from the general surface of the olfactory

epithelium. The study of Rita rita reveals that these micro formation are of great importance in fish life as they are found to be histoecological adaptation which make life easier to with stand in all the environment encountering with prevailing environmental threats (PL 6,7).

The basal cells :

The basal cells(BC) can easily be distinguished, as they are lying irregular above the basement membrane(BM) in layers. These spherical cells are provided with darkly staining oval nucleus having a clear centrally placed nucleolus and uniformly distributed chromatin material in karyoplasms . These cells can be observed anywhere in the olfactory epithelium, but they are sparse and scanty in the proximal and middle region of the initial and middle lamellae in three or four rows. In distal region of all lamellae and in hinder lamellae the basal cells are irregularly arranged in rows just above the basement membrane. At some places the rich aggregation is seen which can be under stood as preparation to migrate in any direction leading to create some formations in the all olfactory epithelium. Similarly due to the pressure of above or under lying cellular components and bursting of goblets these cells

Plate-31 Vertical section of lamella of Rita rita showing pigmentation and deepenings on a lamellar surface processing, histoecological activity in mucosa and submucosa . Magnification x 400

Plate –32 High magnification photograph of lamella tip of Rita rita showing cellular architecture, ciliation, nucleation, receptors and other mucosal and submucosal composition. Magnificationx1000.

BC	Basal cell
ELE	Elevation
GC	Goblet cell
MSA	Mucosa
NCI.SC	Nonciliated supporting cells
PN	Primary neurons
PIG	Pigment Sheath
SMSA	Submucosa
SR	Spindle Shaped receptor

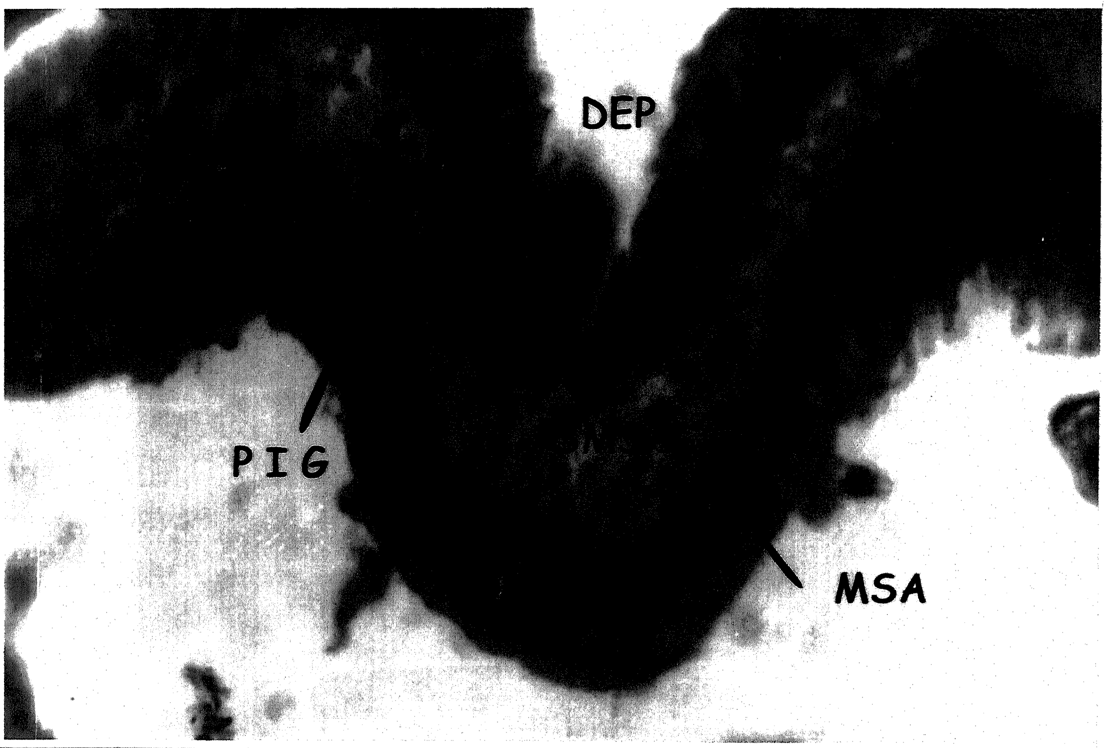


PLATE - 31

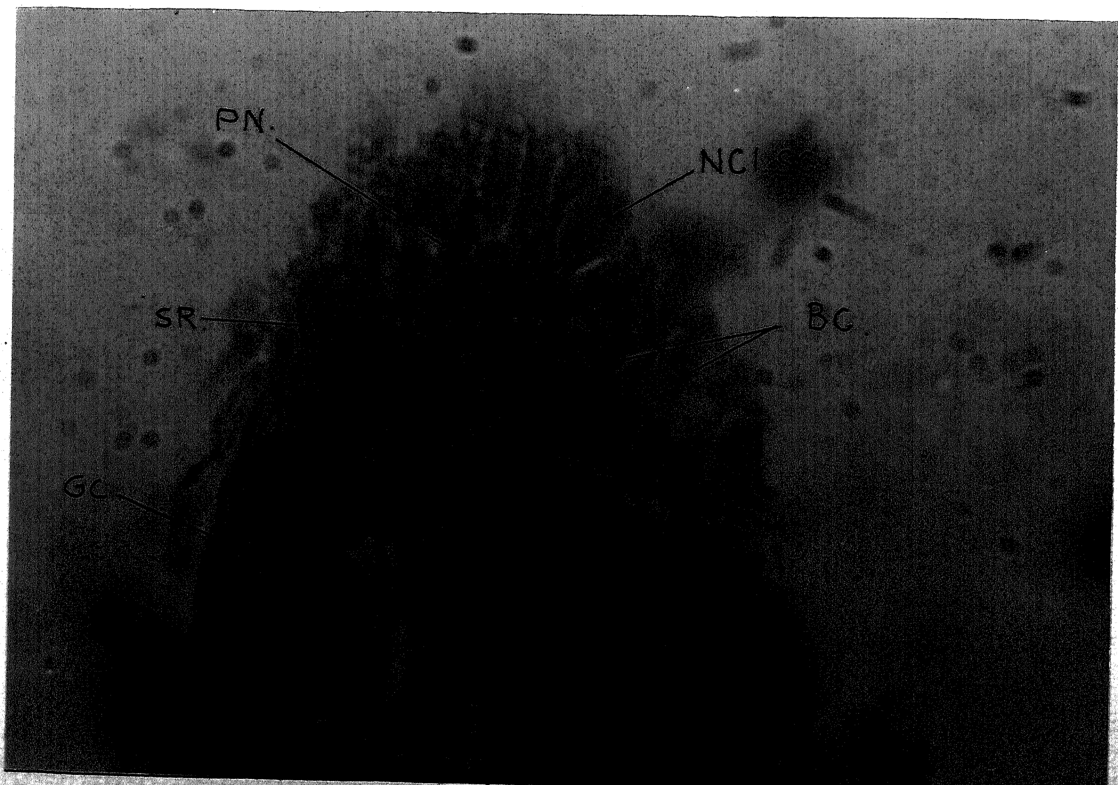


PLATE - 32

migrates from proximal to peripheral zone giving rise to the crupts and other microformations, while in cell ball (C.BALL), bud(BUD) and bifurcation(BI) they shows rich aggregation, formation ultimately giving rise to different types of cell components substituting lamellar bulk causing enhancement of surface area for prompt olfactory reception. This morphogenetic activity in basal cells demonstrate histoecological adaptation in the olfactory epithelium of Rita rita (PL 5, 13, 14, 19, 25, 32, 33, 34, 35)

The submucosa or the central core:

The central core or submucosa(SMSA) is lined on either side by a well defined basement membrane.(BM) It is filled with collagen connective tissues(CON.TIS.FIB) and lymphoid space (LYM) in between the connective tissue fibers. In the distal regions of the lamellae the connective tissues convertes into dense connective tissues, in which no lymph space (LYM) are observed. The submucosa(SMSA) of the hinder lamellae becomes enormously enlarged causing rare distribution of the connective tissue fiber and blood capillaries(BCP,PL 19). The fibroblast cells(FIB) can be observed in initial and middle lamellae and are richly present

in hinder lamellae. The histocytes cells(HIS) and the basal cells can be observed in the connective tissues(PL 14,26) . The blood supply is through the small branch of internal carotid artery, internal jugular vein and lymph is supplied with lymphatic trunck. The fibers of folium olfactorium (FI.OL) run along the basement membrane and joins the nonmedullated nerve fiber(NMN.FIB) to the raphe(RPH). The central core of all the lamellae is in continuation of the central core of the raphe and all the vascular, nervous and cellular supply is passed to the lamellae through it. The branching of sub mucosa is observed only in bifurcation and in the secondary lamellae, while in other micro formations its does not sends its branches(PL 8,9.10,11,24).

The raphe :

The raphe (RPH) is a non ciliated, nonsensory thickening of the olfactory floor, which allows lamellae(LAM) to attach on its either side. It is made up of central core or submucosa (SMSA) with dense collagen fibers (CON.TIS.FIB), basal cells(BC), fibroblast cells(FIB) and histocytes cells(HIS) submerged in the matrix. The non medullated nerve fibers(NMN.FIB) are extending along the

basement membrane and joins the folium olfactorium (FI.OL)coming from lamellae region. The blood capillaries (BCP)are also seen in raphe. In Rita rita the lymph space are clearly visible(PL 4,5).

Beside raphe (RPH) it is observed , that to keep olfactory rosette in rightly projected position, some additional supporting structures are seen in Rita rita and are nomanclated as turger (TUR). This is one of the specific finding of this work. The presence of turger (TUR) in Rita rita is so designed that it controls enormously enlarged rosette with large number of lamellae and keep them properly ejected in olfactory chamber for making prompt reception from circulation of water current (PL 16).

It is also assumed that rosette might be supporting in gaseous exchange , as there is a rich blood supply in raphe and lamellar submucosa, which may be helping the fishes as an additional respiratory device

The accessory sacs :

Plate-33 High magnification photograph of lamellar periphery of Rita rita , showing cellular architecture pattern ciliation, nucleation and exact picture of mucosa and submucosa. The single arrow is showing path way of dendrite of primary neurons, while double showing synaptic contact between primary neuron and spindle shaped receptor cells. Magnificationx1000.

Plate –34 High magnification photograph of distal zone of lamella of Rita rita showing elevation, ciliation , different type of receptor and cellular architecture of mucosa and submucosa. Arrow indicating dendrite and axonal path way Magnification x 1000.

AX.SR	Axon of spindle shaped receptor cell
BC	Basal cell
BCP	Blood capillaries
CI.SC	Ciliated supporting cells
FIB	Fibroblast cell
GC	Goblet cell
PN	Primary neurons
RR	Rod shaped receptor cells
SR	Spindle shaped receptor cells
SY	Synapse

PLATE - 33

PLATE - 34

In Rita rita a well developed ventrolateral accessory nasal sac(VEN.LAT.ACC.NAS.SAC, PL 2,37,38) is found as they are the bottom dwellers, semi sedentary fish. The accessory sac of Rita rita is constituted with non ciliated cuboidal epithelium. It consists of cuboidal supporting cells(CU.SC) , rounded goblet cells(GC) and basal cells (BC). The epithelial lining of the sac is wavy, showing hillock elevations(ELE) and depressions(DEP). The cuboidal supporting cells(CU.SC) with darkly stained oval nucleus are found situated in the periphery. These cells are seen arranged in two or three rows in elevated region of the epithelium, while the neck less rounded goblet cells(GC) are found embedded in the periphery among them . The goblet cells are also seen in two or three rows in region of elevation forming goblet trees. At some places they are observed with empty theca after discharging their mucous content. The basal cells are found lying in three to four rows just above the basement membrane. In the accessory sac the basal cells(BC) are accumulated in large number. In the elevation they shows migratory tendency towards the periphery. Just below the basal cells the wavy basement membrane(BM) lies, which is followed by the elastic connective tissues fibers(CON.TIS.FIB), they are loosely cemented with matrix

and are followed by thin elastic fibers. Within these fibers the fibroblast(FIB) and basal cells are also observed. In the accessory sac of Rita rita blood capillaries(BCP) are also found alongwith the connective tissues. The numbers of sac layer is found varying under the distension conditions of accessory sac. In normal conditions the cuboidal and basal cells are arranged in nine to ten layers while in distended condition they are found in two to three layers only(PL 37,38).

The unidirectional flow of water :

The movement of nasal barbel (NAS.BAR,) and pumping activity of ventro lateral accessory sac (VEN.LAT.ACC.NAS.SAC, PL 1,2), synchronously with the unidirectional beating of cilia(CI) conducts the water current through the anterior tubular nasal opening (ANT.NAS.TUBE) over the anterior most part of the olfactory rosette (RE). From their the water current is directed to the central and the peripheral channels of the olfactory chamber (OLF.CH). The channel are coverged posteriorly in narrow lamellae less region of the olfactory rosette(RE) which is communicated by an aperture to the accessory sac, resulting the water current to the sac after

crossing the entire distance of the rosette(RE) . In this course of circulation, water travels through the inter lamellar space(INT.LAM.SP) and each lamella is properly bathed. The compression of accessory sac causes the exit of water current from posterior nasal opening (POST.NAS.OP). The valvular arrangement of posterior nasal opening (POST. NAS.OP) can only allow the exit of water current, demonstrating unidirectional flow of water through the olfactory chamber.

The continuous and gradual flow of water through the olfactory chamber(OLF.CH) from anterior to posterior nasal openings is regular feature in Rita rita which becomes rapid during forward movement.

The histoecological variations:

A detail study of olfactory epithelium of Rita rita reveals various microformation on the lamellar surface, to cope up with diverse ecological condition. These structures help the fish for prompt olfactory reception in changed environmental conditions. These formation in the olfactory epithelium can be in form of bifurcations (BI), hillock

Plate-35 High magnification photograph of deepening , elevation, ciliation , different types of receptor and cellurlar architecture of mucosa and submucosa. Arrow indicating synaptic contact between primary neuron axons and dendrite of spindle shaped receptor cells. Magnification x1000.

Plate –36 High magnification of lamellar periphery of Rita rita showing various cellular component of mucosa and submucosa. Arrow show axonal pathway of spindle shaped receptor cells. Magnification x1000 ..

AXSR	axon of spindle shaped receptor cells
BCP	Blood capillaries
BL	Blastema cells
BC	Basal cells
CI	Cilia
CI.SC	Ciliated supporting cells
DN.PN	Dendrite of primary neurons
DEP	Deepening
DN.SR	Dendrite of spindle receptor cell
ELE	Elevation
FI.OL	Folium olfactorium
FIB	Fibroblast cell
HIS	Histocytes
OCI	Olfactory cilia
PN	Primary neurons
RR	Rod shaped receptor cells
SY	Synapse
SR	Spindle shaped receptor cells

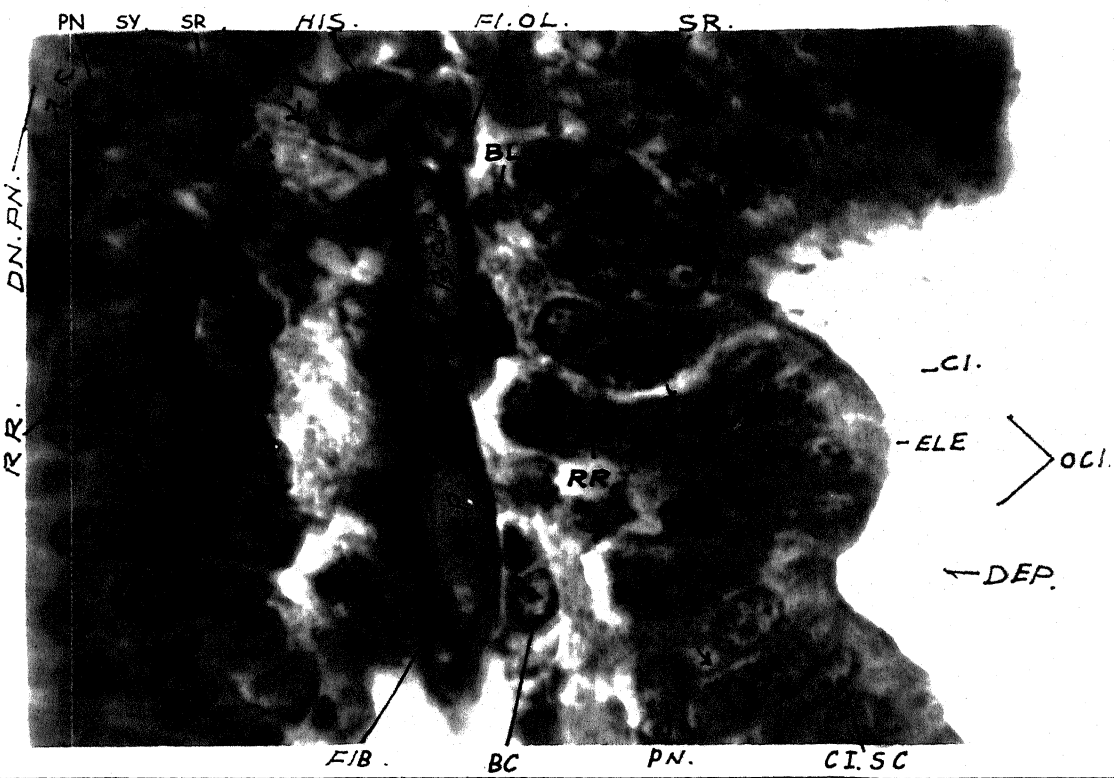


PLATE - 35

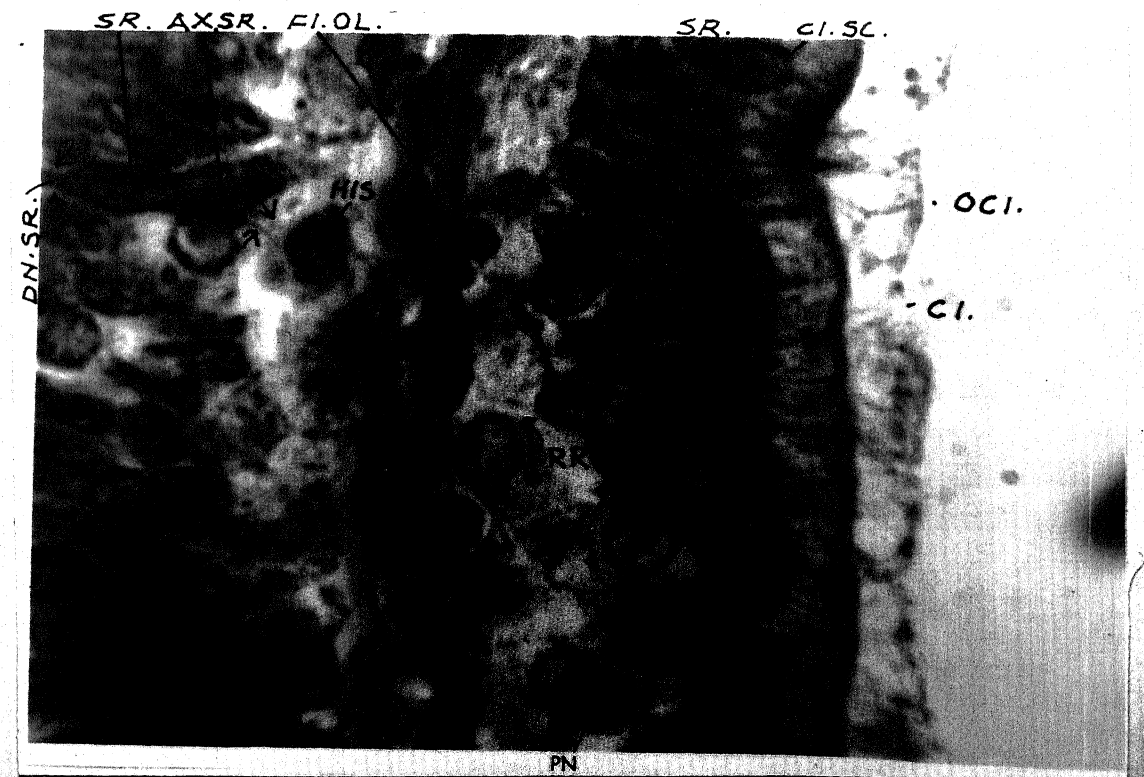


PLATE - 36

Plate-37 Ventro lateral section of rosette of Rita rita its relation of ventro lateral accessory nasal sac along with it cellular composition in mucosal and submucol zone . Magnificationx1000

Plate –38 Ventro lateral section of accessory nasal sac of Rita rita showing mucosal and submucosal cellular composition alongwith vascular connective tissue, pigment and goblet cell supply. Magnification x400

BCP	Blood capillaries
BM	Basement membrane
CON.TIS.FIB	Connective tissue fibers
CU.SC	Cuboidal supporting cells
GS	Goblet cell
HIL.ELE	Hillock elevation
INT.LAM.SP	Inter lamellar space
LAM	Lamellae
MSA	Mucosa
OL.NE	Olfactory nerve
PIG	Pigment sheath
RE	Rosette
SMSA	Submucosa
VEN.LAT.ACC.NAS	Ventro lateral accessory nasal sac.
W.OLF.CH	Wall of olfactory chamber

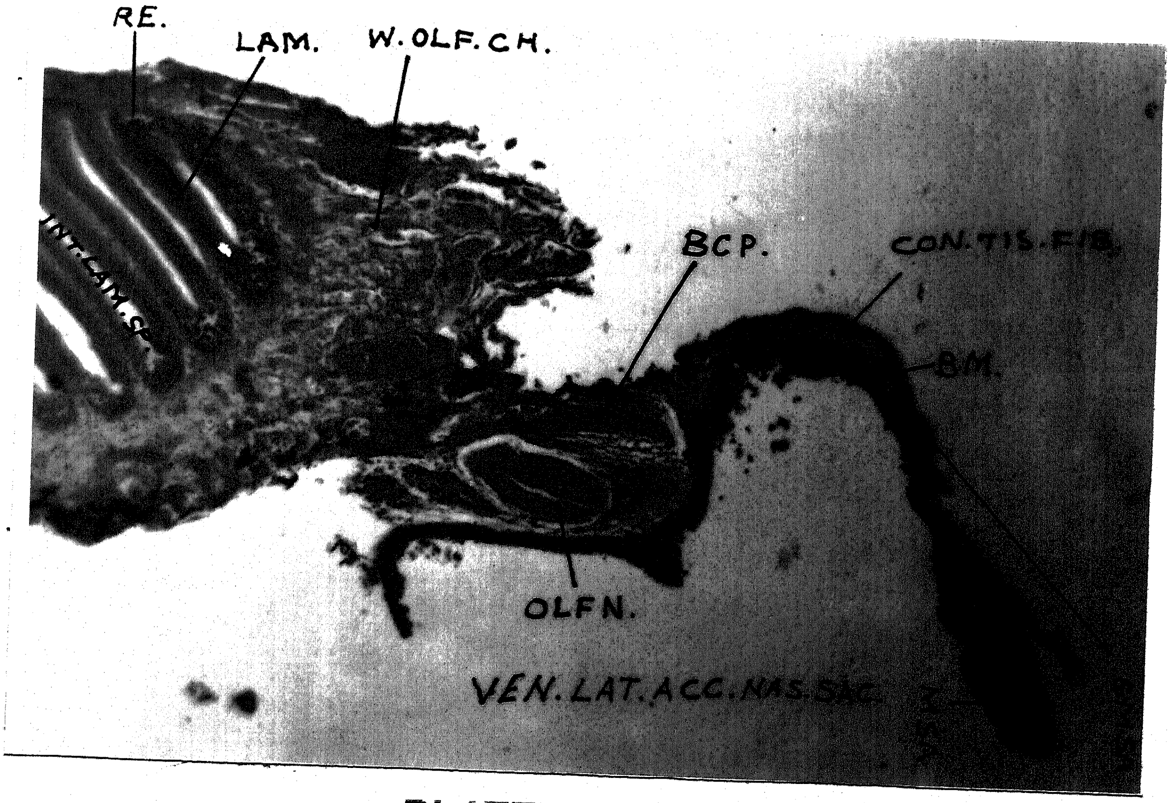


PLATE - 37

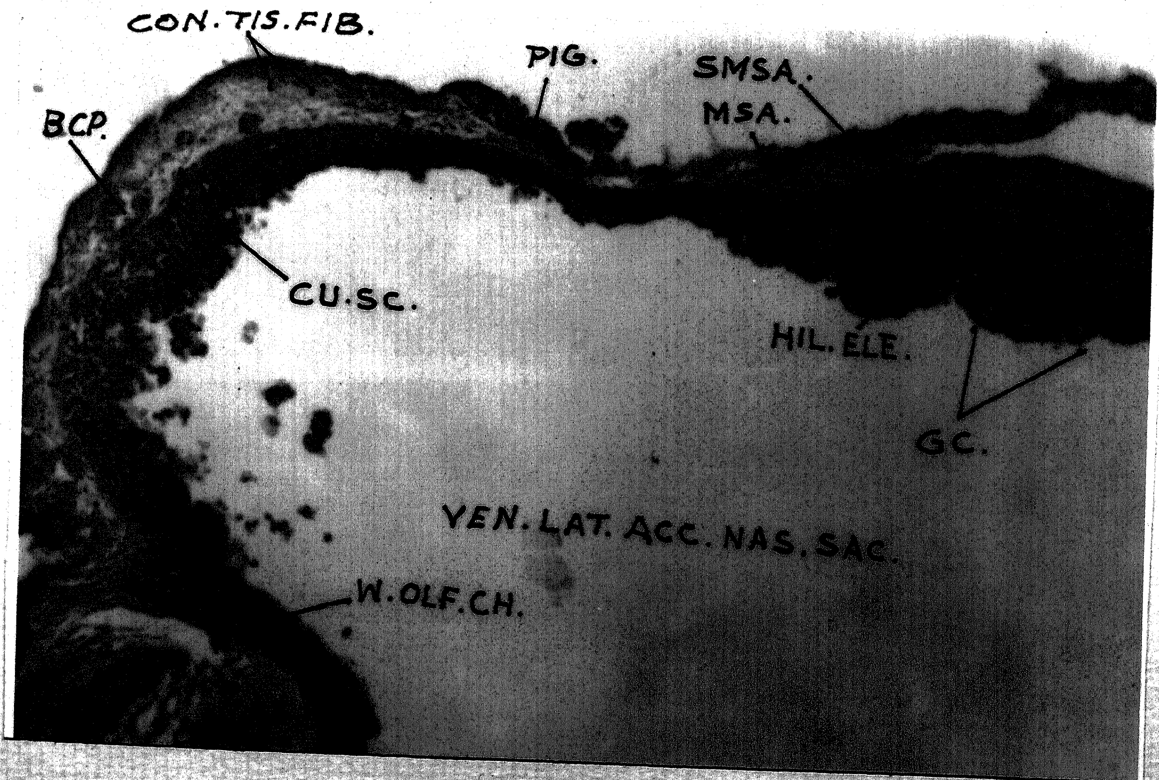


PLATE - 38

elevation (ELE), tubular, flask, funnel shaped depression (DEP), crupts (CRY) or vacuole like structures. In Rita rita the hinder lamellae are deprived of these formations as these are old and worn out set of lamellae, while in initial and middle lamellae good deal of micro formations are present as they are youngest lamellae participating actively in receptory functions.

In the initial and middle lamellae the peripheral surface is richly supplied with goblet cells (GC). Due to the bursting of these cells exposed crupts(CRY)are formed, which may be of funnel, tube or flask shapes projecting out sensory cilia in the inter lamellar space (INT.LAM.SP, PL 21, 23, 24,26,27,29,31). The flow of basal cells(BC) in the empty spaces created by bursting of goblet cells(GC) give rise to hillock elevation(ELE).These hillock elevations (ELE) changes into minor lamella(MINL) when the flow of basal cell (BC) in that region is abundant. The minor lamella (MINL) formation is observed basely(PL 8,9) , medially(PL 10)and terminally(PL 11),as histoecological modification of Rita rita. These are the off shoot from mother lamella, in which mucosal and submucosal substitution is seen as independent formation. At some

places mucosa of minor and mother lamella fuses, and forms unexposed crupts of variable shapes and sizes.(PL 8,9).Beside this, in Rita rita formation of bud(BUD)on the lateral surface is also noticed and it is assumed that this increase the receptory surface after its detachment from mother lamella(PL 12,13).The"U-shaped" structures formed by the bending of lamellar tip in middle lamellae also increase the olfactory area(PL 6,25).The cell balls (C.BALL) are found arranged occasionally against the distal tip of lamellae and can be assumed as cellular component substitution device, causing addition in lamellar bulk(PL 12,14,15).The microformation in the mucosa and enhancement in lamellar bulk increases the surface area of olfactory reception making fish more component for discharging physiological and other activities successfully and more promptly.

The unique change notice in Rita rita is the turger (TUR PL 16) of lamellae, due to the extension of raphe at the lamellar surface which keeps the lamellae erected for proper water bath. This supporting structure not only helps in olfactory reception, but can be assumed as respiratory

device, as it is richly supplied with blood vessels and nervous components.

The accessory sac(ACC.NAS.SAC,PL 2,37,38) in *Rita rita* is also an additional device to pour more water on olfactory surface and retain it in its contacts for longer period. It may also be assumed that retention of water in accessory sac is to neutralized the allow more and more contact of circulating water with olfactory and vascular surface performing sensory reception as well as aiding in gaseous exchange.

Ecological coefficient of Rita rita

It is calculated by taking the length as parameter of mesencephalon , telencephalon and by measuring the area of two retina and both the rosette. By comparing the former and latter parameters, the effectiveness of the olfactory and optic faculties can be assessed approximately.

Five fishes ranging from 150mm to 315 mm were selected for calculating the ecological coefficient. It was observed that the length of brain and number of lamellae increases successively with the size of the fish (Table 1) . The size of mesencephalon ranges from 2.40mm to 3.12mm in length and that of telencephalon from 3.25mm to 4.34mm. The ecological coefficient ranges from 135.41 to 139.10 . The area of two retina and rosette was measured by usual method. It was observed that olfactory area ranges from 170.27 to while retinal area from 35.08 to 52.41 by calculating ecological coefficient which ranges from 485.37 to 764.45 it is found that olfactory faculty is well developed than optic faculty. Thus Rita rita is considered as macrosmatic or 'nose fish'

Table 1 Ecological coefficient of Rita rita

S. No	Total length mm	No of Lamellae	Total length of Brain mm	Length of Telencephalon mm	Length of Mesence-phalon mm	E.C=length of telen x100 / length of Mesen	Retinal Area mm^2	Olfactory Area mm^2	Ex= OAx100 / RA
1	150	45 44	10.40	3.25	2.40	135.41	35.08	170.27	485.37
2	226	60 60	11.39	3,68	2.76	133.33	47.34	250.14	528.39
3	288	78 76	12.76	4,10	2.98	137.57	48.73	265.57	544.98
4	310	84 84	13.04	4,29	3.12	131.50	52.61	353.57	672.05
5	315	88 87	13.04	4.34	3.12	139.10	52.61	402.28	764.45
						135.38			899.04

Plate-39 Photograph of dorso lateral view of Anabas testudineus showing the position of nostril and nasal barbel.

Plate –40 Photograph of dorso lateral view of Anabas testudineus , showing the position of rosette and its correlation with the position of ethmoidal and lacrymal accessory nasal sac.

ANT.NAS.OP	Anterior nasal opening
EY	Eye
ETH.SAC	Ethmoid sac
LAC.SAC	Lacrymal sac
RE	Rosette
POST.NAS.OP	Posterior nasal opening

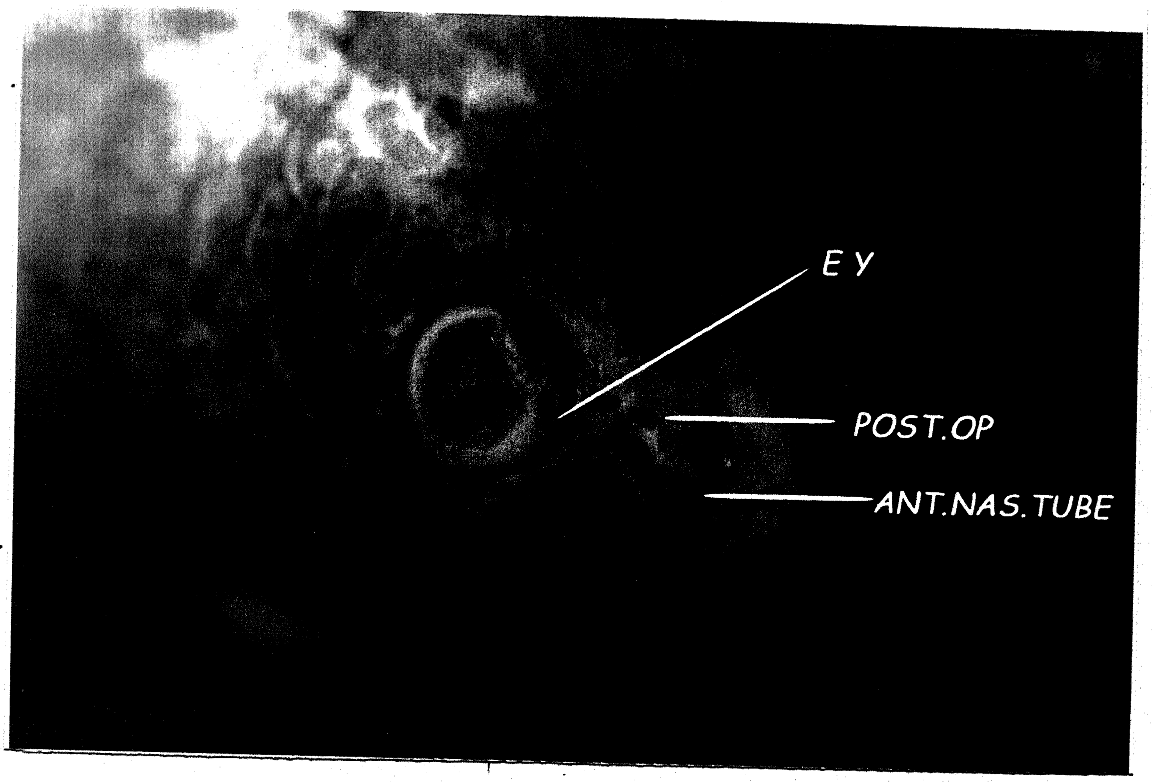


PLATE - 39

PLATE - 40

HISTOLOGICAL OBSERVATION OF Anabas testudineus

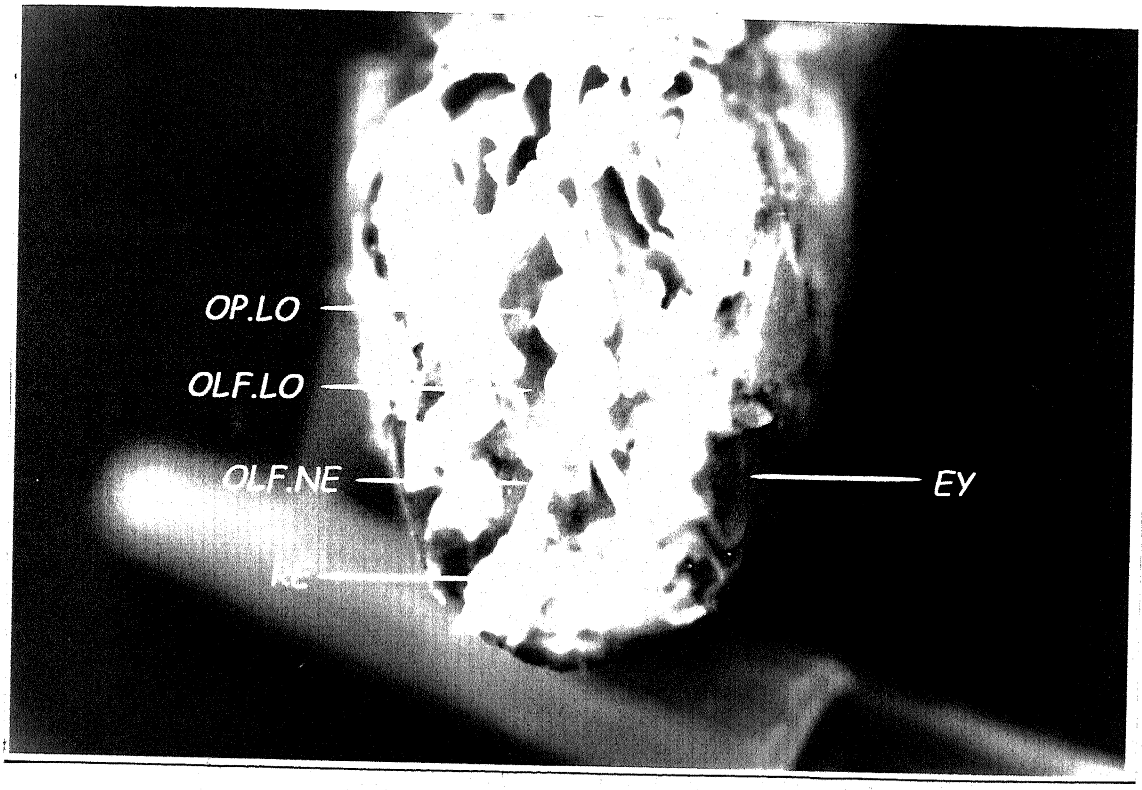
In Anabas testudinues the olfactory chamber lies on the dorsolateral surface of the snout, anterior to and at the level of the eyes. Each chamber communicates outside by two openings: Anterior nasal opening (ANT.NAS.OP) which is a small, tubular and forwardly directed and a circular posterior nasal opening (POST.NAS.OP. PL 39,40).This opening is covered by a small flap. The anterior margin of the chamber is delimited by the first spine of the lachrymal bone, while the posterior is merged with the exhalent pore. In Anabas testudinues both the openings are found situated at the distance of 4mm in 115mm long specimen.

Each olfactory chamber is lined by a olfactory rosette (RE , PL 40) , which is quadrangular in shape. The olfactory rosette(RE), consist of seven to ten fingered like projections called lamella(LAM), which arises directly from the floor of the chamber(FL.OLF.CH, PL 42,43,44) . The number of lamellae(LAM) sometimes varies in the left and right rosette, but they never exceed than ten. These lamellae are parallel arranged to the long axis of the body of A.testudineus. The lamellae are attached with the floor of the olfactory chamber

Plate-41 Photograph of dorsal dissection of head of Anabas testudineus showing brain architectural pattern and connection of olfactory nerve with rapheless rosette.

Plate –42 Vertical section of rosette showing orientation and position of lamellar attachment in olfactory chamber. Magnificationx100

BCP	Blood capillaries
CE	Cerebellum
CON.TIS.FIB	Connective tissue fibers
EY	Eye
INT.LAM.SP.	Inter lamellar space
NMN	Nonmedullated nerve fiber
OP.LO	Optic lobe
OLF.LO	Olfactory lobe
OLF.NE	Olfactory nerve
PR.LAM	Primary lamellae
RE	Rosette
SEC.LAM	Secondary lamella



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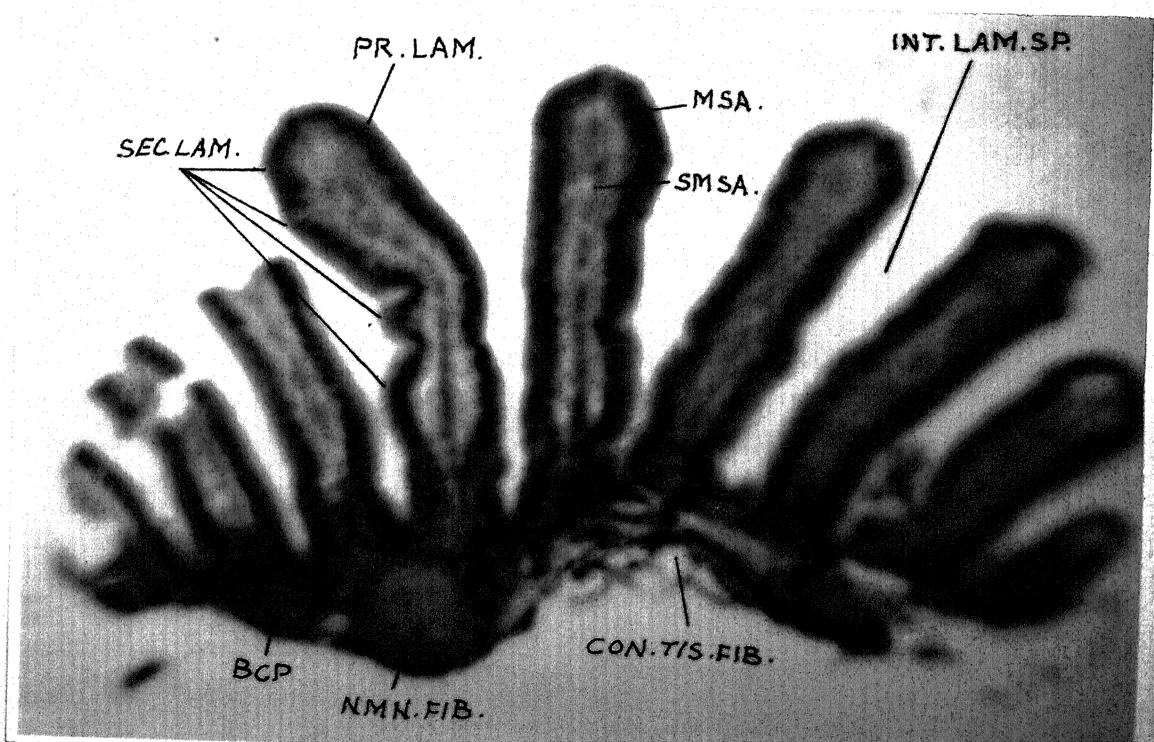


PLATE - 42

by their vertical side and remain free on dorsal surface, maintaning inter lamellar space(INT.LAM.SP, PL 42,44).The raphe is found absent in the rosette of this fish.

In Anabas testudineus a pair of accessory nasal sac are present which are situated in relation to lacrymal and ethmoidal bones and are well communicated with olfactory chamber. They are know as lacrymal (LAC. ACC. NAS. SAC) and ethmoidal accessory nasal sac(ETH.ACC. NAS. SAC, PL 40,57,58,59,60). The communication of both the nasal sac with olfactory chamber cavity is through posterior nasal opening (POST. NAS.OP) The volume of accessory nasal sac is fluctuable and with the protrucible activity of snout and the movement of other cranial bones related to olfactory chamber.

In this fish olfactory bulbs(OLF.BL)are small, sessile, supplied with nervous content by olfactory nerve(OLF.NE) which extends from the olfactory bulb to the olfactory rosette (RE, PL. 41). The blood supply in this fish is mainly by a smaller branch of internal carotid artery, and it is collected from here by internal juglar vein. The lymphatic supply in the olfactory chamber is found through juglar lymphatic trunk,

which is distributed in submucosa forming lymph spaces at variable positions.

In Anabas testudineus each lamellae is a composite structure and are different with the lamellae of other rosette. Each lamellae can be differentiated into two zones : sub-mucosa (SMSA) and mucosa (MSA , PL. 42,43,44)

The submucosa (SMSA) is comprised of connective tissue fiber (CON.TIS.FIB), fibroblast (FIB) , histocytes (HIS), blastema cells (BL) and components of vascular and nervous elements. The submucosa (SMSA)in Anabas testudineus is typically wavy projecting to mucosal zone very frequently (PL. 45, 46). The submucosa is lined by mucosa possessing multilayer basal and supporting zones with respect to other cellular elements. The basement membrane is also wavy and stand as partition between them . In Anabas testudineus relative thickness of mucosa(MSA) and submucosa (SMSA) varies from fish to fish. In the olfactory epithelium of this fish few mucus or goblet cells(GC) are scantly present(PL. 51) . Histologically it is observed that olfactory epithelium exhibit moderate morphogentic activity. This leads in the formation of hillock

elevation(ELE) or depression(DEP , PL 48) . At the peripheral surface of the lamellae the olfactory epithelium is provided with number of dimunative out growth , which ultimately give rise to secondary lamellae(SEC.LAM).

In secondary lamellae(SEC.LAM) the undifferentiated cells are present forming a thin boundary. The eight to nine secondary lamellae are visible on some of the prominent middle lamellae of Anabas testudineus . These secondary foldings covers the whole primary lamellae(PR.LAM). All the primary lamellae(PR.LAM) do not show synchronous development of secondary lamellae (SEC.LAM, PL 42,44) . The observation reveals that sometimes only one or two primary lamellae would have few secondary lamellae, but rest of them remains free from these outgrowth or only one side of the primary lamellae (PR.LAM) may bear well developed secondary lamellae (SEC.LAM), while the others would have either none or have weakly developed secondary lamellae(SEC.LAM,PL 42,43,44). The submucosa of secondary lamellae is surrounded by the olfactory epithelium of primary lamellae, but at the dorsal tip it is often replaced by stratified indifferent epithelium. Below which three to four layered loose basal zone(BCZ) is present.

Plate-43 Vertical section of rosette of Anabas testudineus showing passage of blood supply , connective tissue supply and other submucosal content to lamella through floor of olfactory chamber. Epithelium projection in from of lamellar outgrowth is also prominently visible. Magnification x 100

Plate –44 Vertical section of rosette of Anabas testudineus showing a pair of lamellae and histoecological formation of bud to inter lamellar space. Magnification x 100.

BUD.	Bud
BCP	Blood capillaries
CON.TIS.FIB	Connective tissue fibers
DI.LAM	Distal lamellae
EPI.OLF.CH	Epithelium of olfactory chamber
FL.OLF.CH	Floor of olfactory chamber
INT.LAM.SP	Inter lamellar space
MSA	Mucosa
NMN.FIB	Nonmedullated nerve fibers
PRO.LAM	Proximal lamellae
SEC.LAM	Secondary lamellae
SMSA	Submucosa

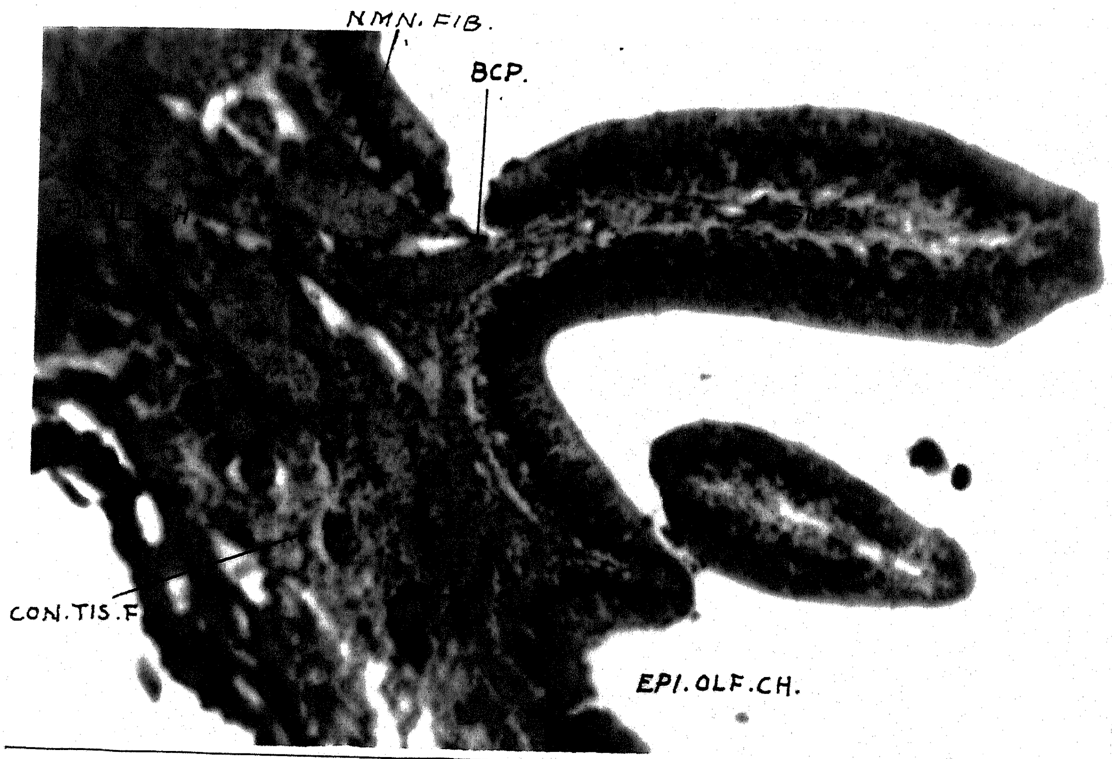


PLATE - 43

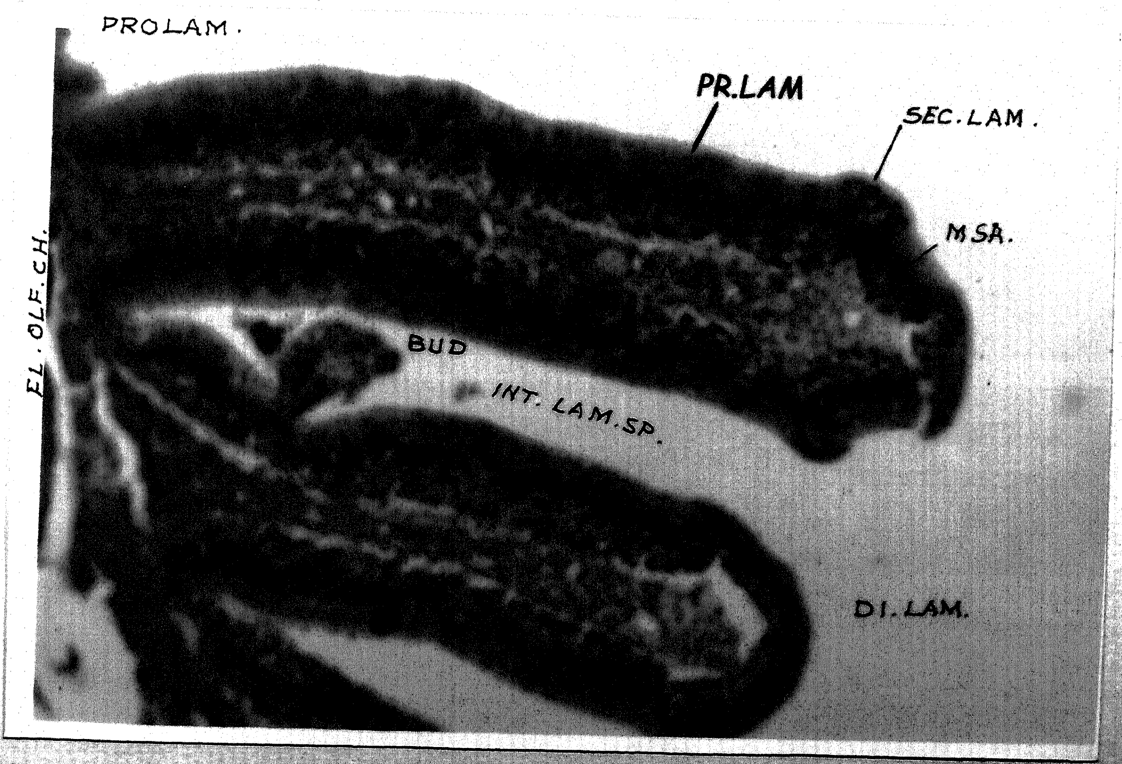


PLATE - 44

In Anabas testudineus rosette is so built that anterior lamellae are with uniform surface, where as middle one shows multipleaction in their mucosal zone , exhibiting secondary lamellae in the shape of cueniform, filiform and fungiform shapes (PL 45,46,47). Submucosa in such lamellae is bulky and reveals lymphatic, fibroblast, myotomal bundles and different types of connective tissue fibers(PL 45,46, 47,51,52). The middle zone of lamellae has grooves of different type , which makes surface totally irregular, enhancing olfactory surface area due to more concentration of receptors cells in such specified zones. The terminal part of such lamellae is very much potential as of submucosal sends its off shoots to mucosal zone, promptly supplying nutritiive ,supporting and protective elements. The filiform, fungiform and cueniform secondary lamellae receive total submucosal contents giving an impression of self sufficient zone, performing functions like a rosette in this fish (PL 45,46,47,48)

The olfactory epithelium of Anabas testudineus is a composition of following cell types: supporting cells, receptor cells and basal cells. In the lamellae of young fish

the receptor cells and supporting cells are uniformly distributed, but after the formation of secondary lamellae (SEC.LAM), receptor cells arranges in groups . In this fish goblet cells are scantly supplied at the peripheral surface, but their existence cannot be denied.

The Supporting Cells :

Supporting cells are arranged at variable depth in the mucosa (MSA.) of olfactory epithelium of Anabas testudineus. Thus it is recognized as pseudostratified columnar epithelium. The supporting or sustentacular cells (SC) can be easily distinguished , due to their large nuclei in which nucleolus and chromatin material are clearly visible. The supporting cells (SC) provide mechanical support and their cilia contributes in the circulation of mucus and water. The sustentacular cells consist of two ends: the distal end and the proximal end. The distal end of the supporting cells is broad, columnar and reaches the superficial surface where the basal bodies having cilia are implanted, while the proximal generally reaches up to the basement membrane(BM). The nuclei of the supporting cell is located in the lower part of the cell and don't form any definite row.

Plate-45 Vertical Section of lamellar of Anabas Testudineus showing submucosal offshoot to mucosal zone. Lamella is in its initial stage and no outgrowth is seen on its surface. Supporting cells, receptor cells, nonmedullated nerve fiber bundles and other submucosal and mucosal components are visible. Magnification x 400

Plate –46 Vertical section of lamella showing initiation of formation of secondary lamella with the result of flow of submucosal content to mucosal zone pushing it out as dimunative outgrowth. Cellular composition of mucosa and submucosa with respect to supporting cells. The basal zone is clearly distinguishable, showing initiation of morphogenetic activity in submucosal and mucosal zone as histoecological changes in lamella. Magnification x 400

BCP	Blood capillaries
BC	Basal cell
BCZ	Basal cell zone
CON,TIS.FIB	Connective tissue fibers
FIB	Fibroblast
FI.OL	Folium Olfactorium
HIS	Histocyte
LYM	Lymph space
MSA	Mucosa
NCI.SC	Nonciliated supporting cell
NMN.FIB	Nonmedullated fibers
PN	Primary neuron
SN	Secondary neuron
SR	Spindle shaped receptor cells
SMSA	Submucosa
SCZ	Supporting cell zone

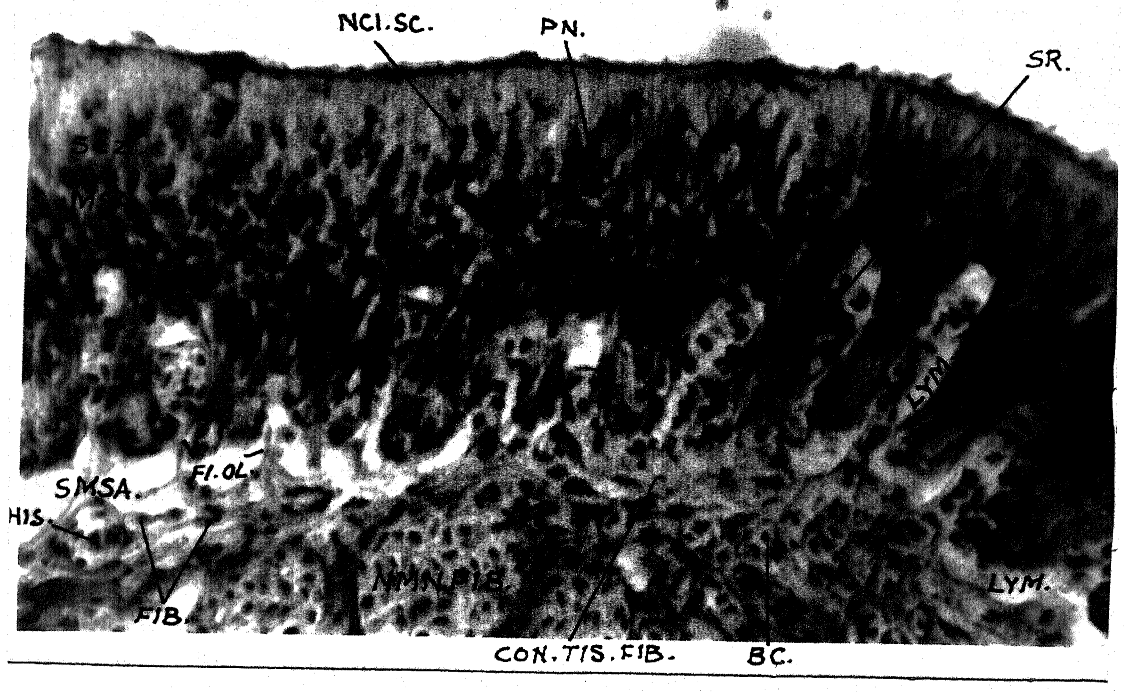


PLATE - 45

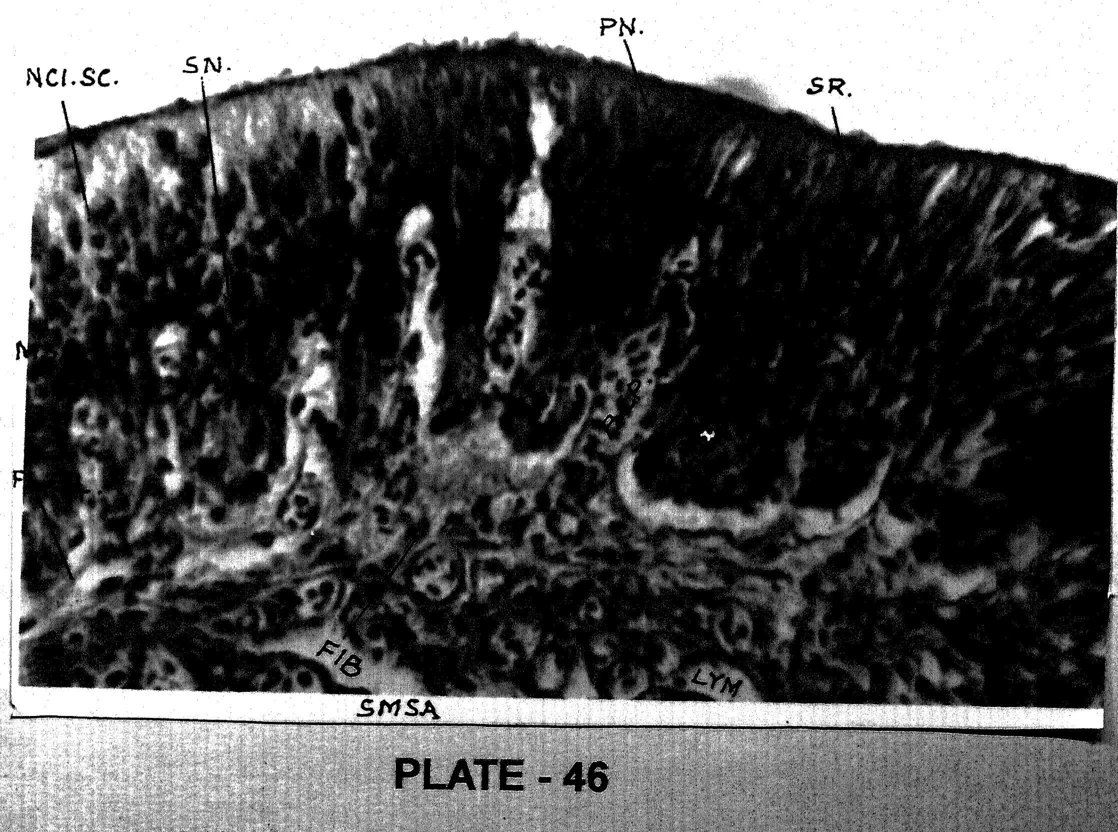


PLATE - 46

Plate-47 Vertical section of lamella of <u>Anabas</u> <u>testudineus</u> showing flow of submucosal content to mucosal zone forming filiform secondary lamellae. Other components of mucosa and submucosa is prominently visible magnification x 400

Plate –48 Vertical section of lamella of <u>Anabas</u> <u>testedineus</u> showing perfect morphogenetic activity of cell resulting in the form of prominent elevation and depression. Dominant offshoot are seen in mucosal zone and flow of different types of cell to respective zone, as a result of histoecological in lamellae. Magnification x 400

BCZ	Basal cell zone
CI	Cilia
CI.SC	Ciliated supporting cell
CON.TIS.FIB	Connective tissue fiber
DEP	Deepening
EL	Elevation
FIB	Fibroblast cell
HIS	Histocytes
LYM	Lymph space
MSA	Mucosa
MIG.BC	Migratory basal cell
NCI.SC	Nonciliated supporting cell
PN	Primary neuron
SR	Spindle shaped receptor cells
SMSA	Submucosa
SCZ	Supporting cell zone.

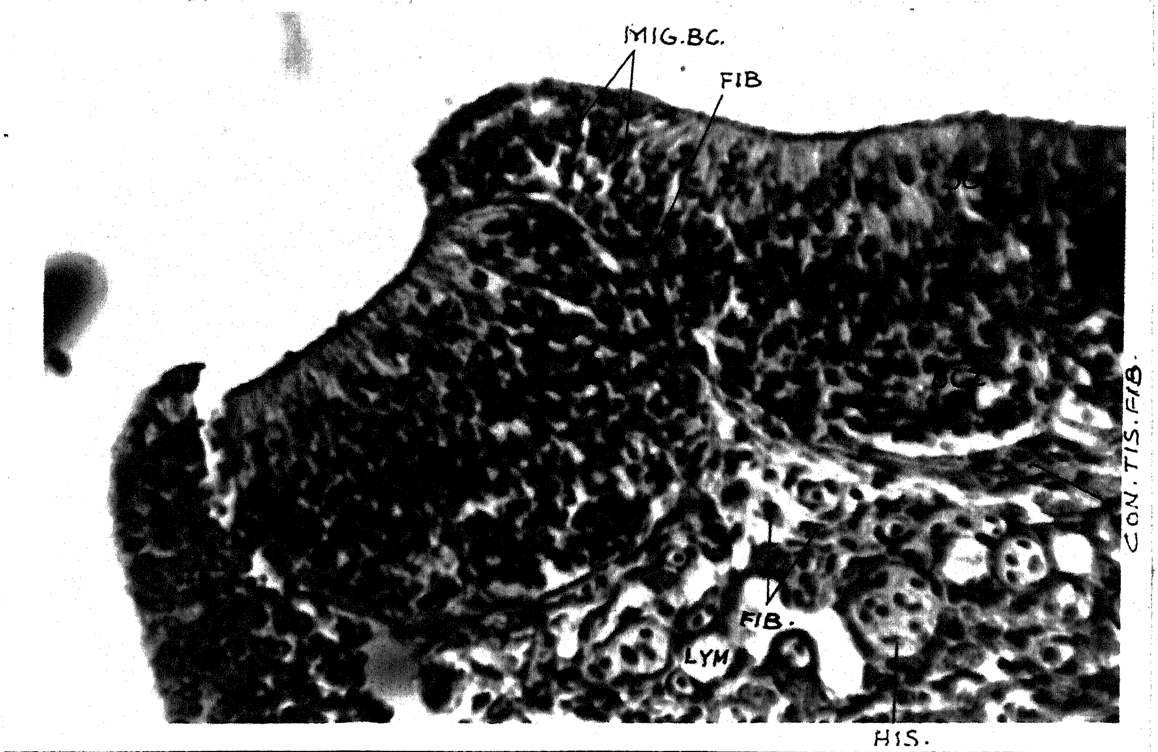


PLATE - 47

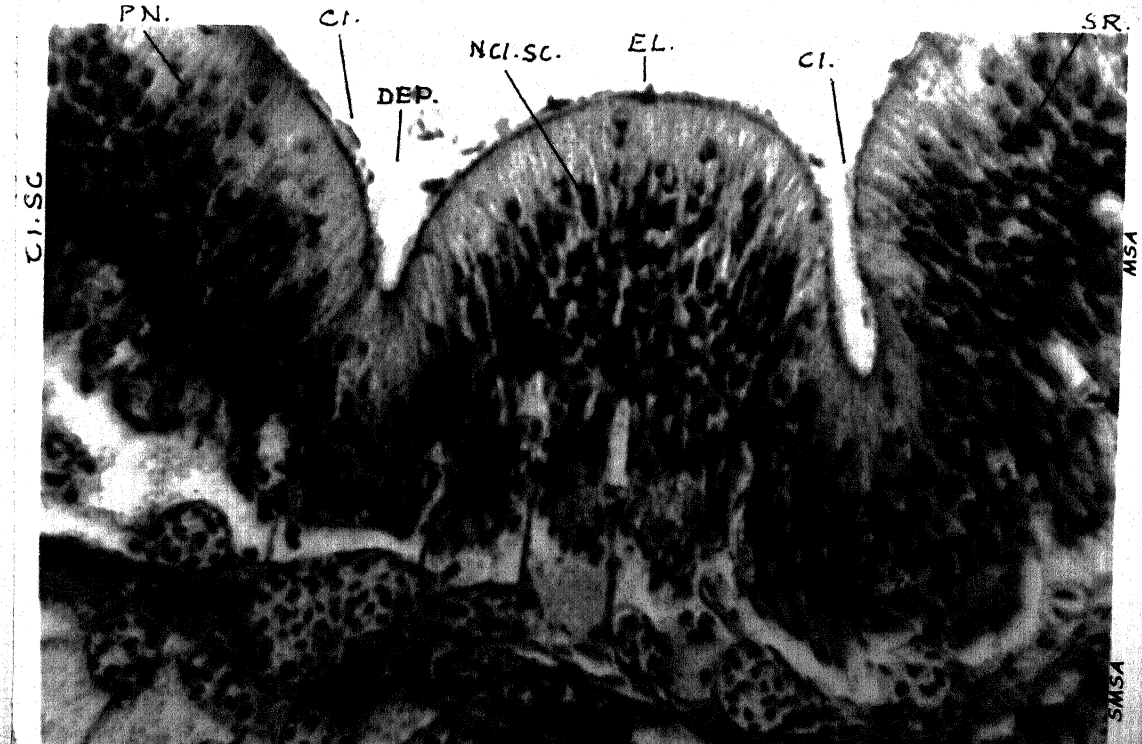


PLATE - 48

In <u>Anabas</u> <u>testudineus</u> the supporting cells can be distinguished as : ciliated (CI.SC) and non ciliated cell(NCI.SC). The ciliated supporting cells(CI.SC) are not so common in this fish. These cells are found mostly in the slopes of the fungiform secondary lamellae(SEC.LAM, PL 48) and also at inter lamellar junction(PL 56) . The nucleus of ciliated supporting cells(CI. SC) have oval and elongated nuclei with clearly visible chromatin material(PL 53,54,56) . The non ciliated supporting cells (NCI.SC) are common and occupy the greater part of the olfactory epithelium. The accumulation of these cells are commonly noticed in the elevation(ELE, PL 48,49,51,53,55) of lamellar surface. These cells are also found present among other cellular components in between basal(BCZ) and supporting zones(SCZ). The non ciliated supporting cells(NCI.SC) have rounded body with inconspicuous apical and lower limbs. The nucleus is of varied shapes and acquires dark stain with haematoxylin (PL 53,54,55) .

As in <u>Anabas</u> <u>testudineus</u> the number of goblet cells(GC) is less, the supporting cells performs mucus secretary activity in addition to the supporting function(PL

51) . This way they compensates the absence of goblet cells. Under the condition of muciferous activity, nonciliated supporting cells(NCI.SC) forms mucopolysaccharide content within apical limb and pushes the nuclear and other contents to the lower limb. Thus the upper part of these cells gradually converts into theca which act as a reservoir for mucus content. The noncilated supporting cells also contributes in the formation of major part of mucosa(MSA) of accessory nasal sacs(ACC.NAS.SAC). In this structure they show tremendous muciferous activity forming greater bulk of accumulation of mucous secretory goblet cells. In accessory nasal sacs nonciliated supporting cells are of cuboidal shape(CU.SC, PL 59,60), having oblong body with prominently visible nucleus. These cells form three to four regular layers in supporting zone of the mucosa of accessory nasal sac .

The receptor cells:

The olfactory mucosa(MSA) of <u>Anabas</u> <u>testudineus</u> is richly supplied with receptor cells of varying shapes and sizes. These cells are totally absent in the mucosa of accessory nasal sac. The receptor cells or the sensory cells

Plate-49 Vertical section of tip of lamella in Anabas testedineus showing submucosal off shoot penetration in mucosa along with cellular architectural pattern of both the zones magnification x400

Plate 50 Vertical section of lamella of A.testudineus showing minor lamella formation through floor of mucular and cellular supply to lamellae from floor of olfactory chamber as prominent morphogenetic activity as histoecological changes are demonstrated. Magnification x 400.

BCP	Blood capillaries
BCZ	Basal cell zone
CON.TIS.FIB	Connective tissue fibers
CI	Cilia
DI.LAM	Distal lamella
FIB	Fibroblast cell
FL.OLF.CH	Floor of olfactory chamber
HIS	Histocytes
INT.LAM.SP	Inter lamellar space
LYM	Lymph space
MIN.LAM	Minor lamellae
MSA	Mucosa
NMN.FIB	Non medullated nerve fiber
NCI.SC.	Non ciliated supporting cells
PN	Primary neurons
SR	Spindle, shaped receptor cells
SN	Secondary neurons
SMSA	Submucosa
SCZ	Supporting cell zone

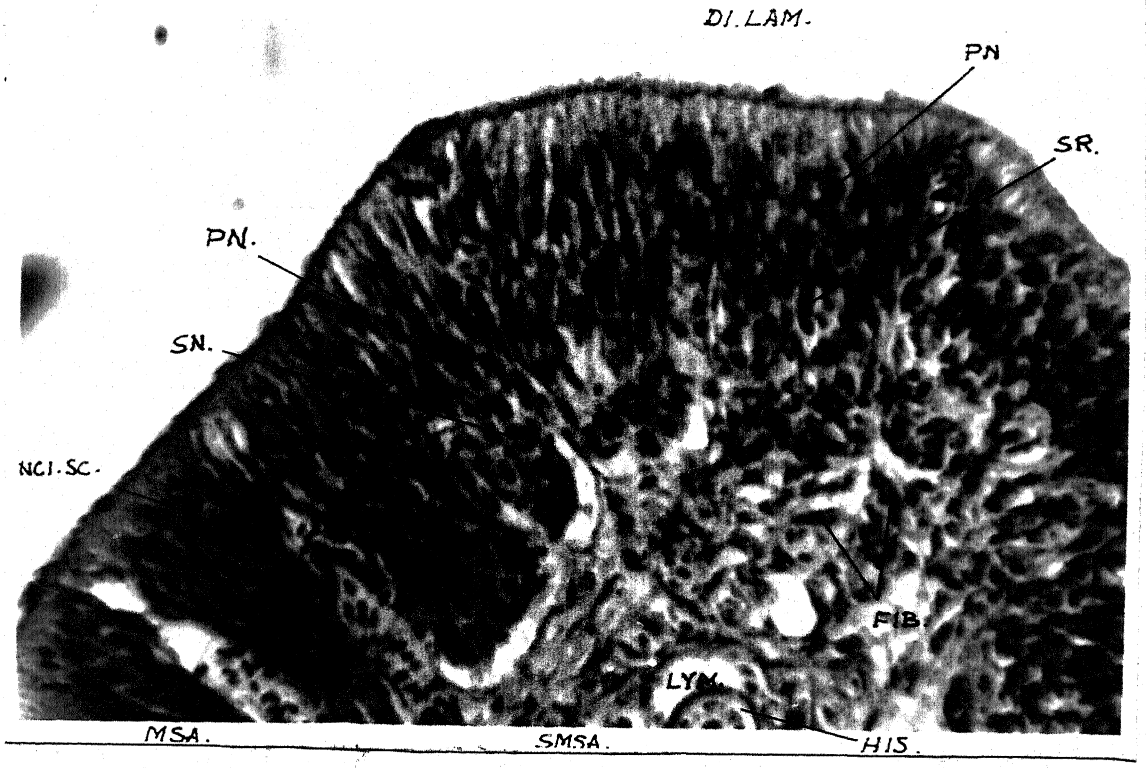


PLATE - 49

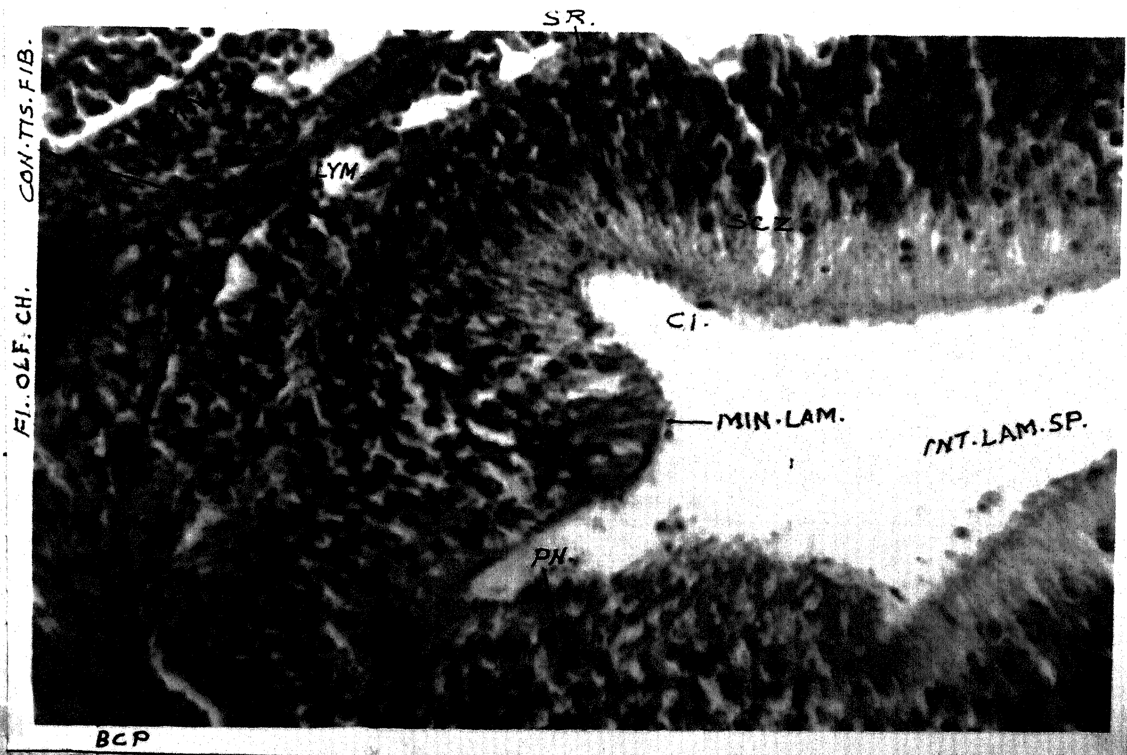


PLATE - 50

can be recognized by their rounded, darkly staining nuclei, which lies generally just in front of the nuclei of the supporting cells. The nuclei of these cells don't form any definite row. The dendrites(DN) are thin and of varying length depending on the depth at which the sensory cell is situated.

When the secondary lamellae(SEC.LAM) developes in mature fish, the receptor cells become grouped in depression(DEP). The axon of receptor cells comes together near the basement membrane(BM) and joins to form folium olfactorium (FI.OL, PL 52,55) , which runs up to the olfactory bulb. There are number of folia olfactoria (FI.OL, PL 45,46) visible in the central core of the lamellae. In Anabas testudineus three types of receptor cells are identified: Primary neuron(PN); secondary neuron(SN) and spindle shaped receptor cells(SR). Primary neurons(PN) are confined in the supporting zone(SCZ). These cells are uniformly distributed in lamellar mucosa and shows no sign of accumulation any where in the olfactory epithelium. Primary neuron(PN) has bulbuls body with more or less elongated nucleus. The chromatin material is uniformly distributed in karyoplasms (PL 48,52,53,54,55,56). This cells

acquires prominent haematoxylin stain as compaired to the surrounding cells. The dendrite(DN) of primary neurons are thick, cylindrical and help in sensory reception, while the axons are not traceable as they form synaptic(SY) contact with secondary neuron (SN, PL 52,53,54,56) .

The secondary neurons(SN) are short with poor staining quality. These cells have a conspicuous nucleolus with scattered chromatin material. Some secondary neurons(SN) are found at moderate depths in the mucosa, but they do not send their independent axon(AX) and dendrite(DN) to inner and peripheral region of the lamellae .The dendrites(DN) of these cells are short fibrous structures which meets with the axon(AX) of primary neurons(PN) to form synapse(SY) and axon collectively joints, resulting the formation of folium olfactorium(FI.OL., PL 46,52,54,56). The nucleus in these cells are prominent.

In Anabas testudineus the spindle shaped receptor cells(SR) are also common. They are situated deep within the basal zone (BCZ) and sends their enormously elongated filamentous dendrites (DN) to the peripheral surface of the lamellae(LAM).Axon of spindle shaped receptor cells (AX.

Plate-51 Vertical section through distal end of lamella of A. testudineus showing scanty supply of goblet cells, lymphoid, histocytes and other mucosal and submucosal cellular components are demonstrated. Magnification x 100

Plate 52 High magnifications of lamella of A. testudineus showing submucosal architectural and mucosal cellular component along with different type of receptor cells are demonstrated. Upward and downward arrow indication reveals pathway of dendrite and axon to the respective zone. Magnification x 1000

BC	Basal cell
BCP	Blood capillaries
BCZ	Basal cell zone
BM	Basement membrane
CON.TIS.FIB	Connective tissue fibers
FIB	Fibroblast cell
FI.OL	Folium olfactrorium
GC	Goblet cell
GC.TH	Goblet cell theca
HIS	Histocytes
LYM	Lymph space
MSA	Mucosa
NMN.FIB	Non medullated nerve fibers
NCI.SC	Non ciliated supporting cells
PN	Primary neurons
SMSA	Submucosa
SN	Secondary neuron
SR	Spindle shaped receptor cells
SCZ	Supporting cell zone.

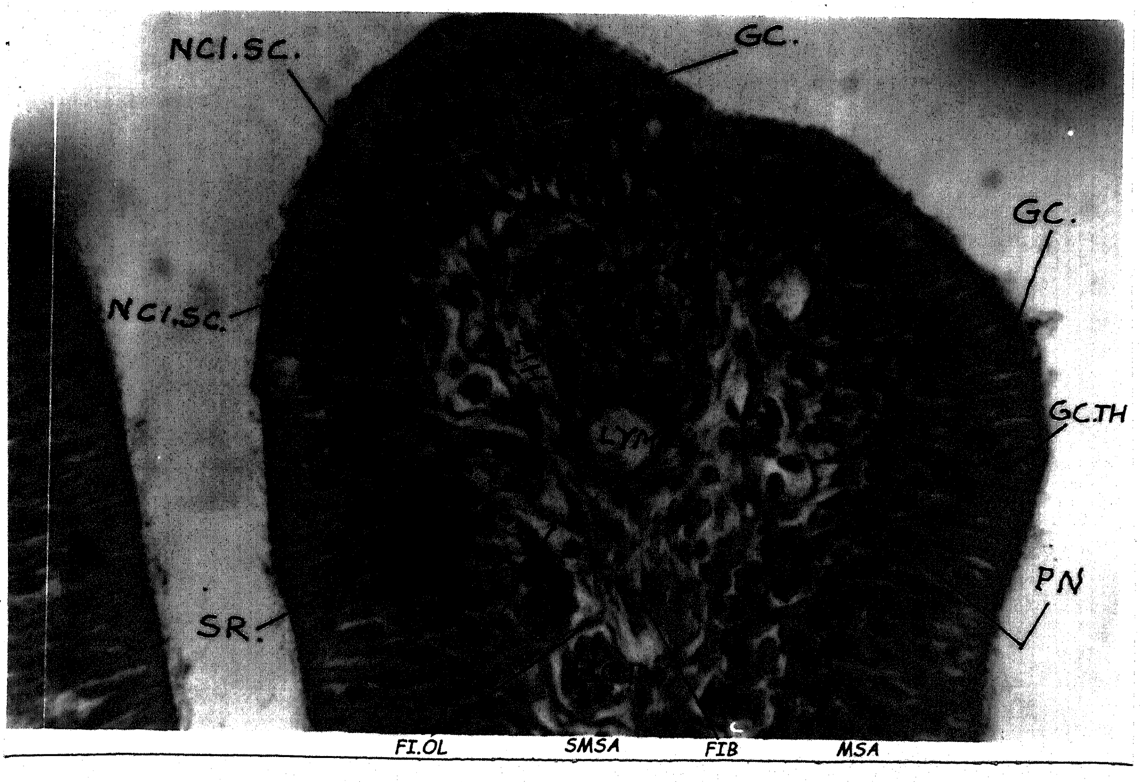


PLATE - 51

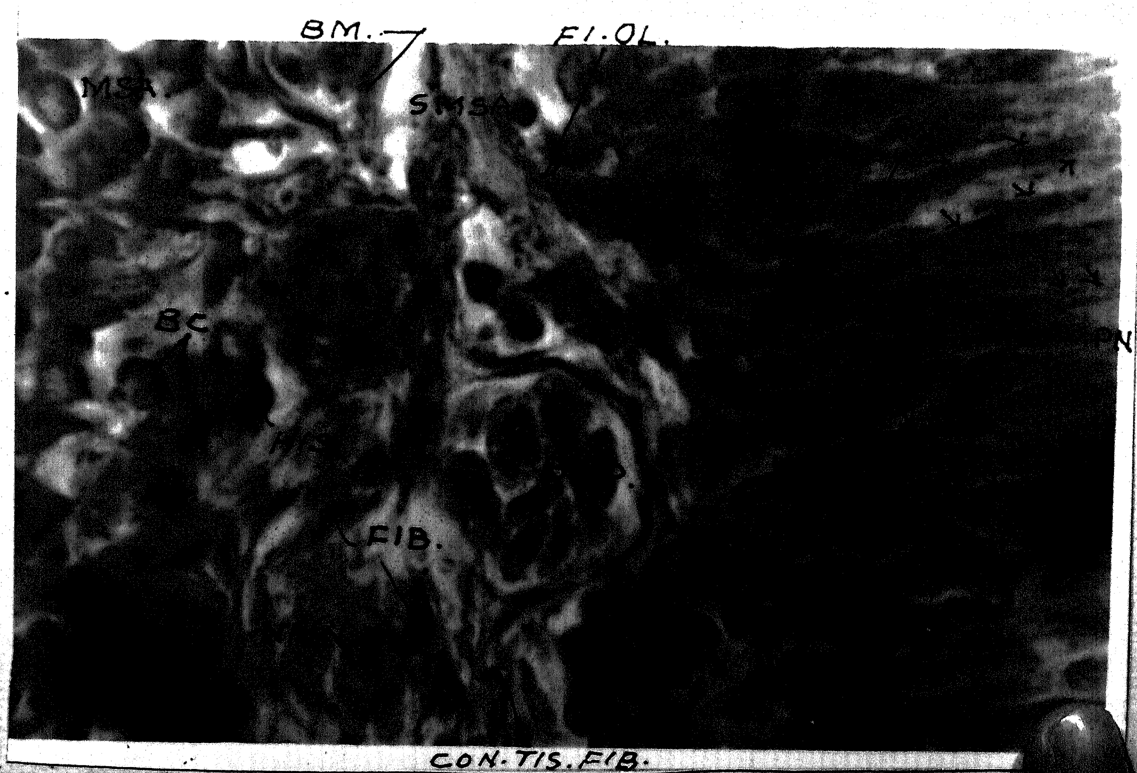


PLATE - 52

Plate-53 High power magnification of dimunative outgrowth on lamellar surface showing inpushing of mucosal and submucosal zone along with ciliation. Arrow indication traced out dendrite and axonal extension to this respective zone. Magnification x 1000

Plate 54 High power magnification of lamellar surface of A. testudineus showing pattern of cellular distribution in mucosa and submucosa. The contact between primary neuron and secondary neuron along with dendrite end axon are indicating by arrows Magnification x 1000.

AX.SN	Axon of secondary neuron
AX.SR	Axon of spindle shaped receptor cells
BC	Basal cell
BCP	Blood capillaries
CI.SC	Ciliated supporting cell
CI	Cilia
DN.PN	Dendrite of primary neuron
FIB	Fibroblast cell
NCI.SC	Nonciliated supporting cell
PN	Primary neuron
SR	Spindle shaped receptor
SMSA	Submucosa
SN	Secondary neuron
SY	Syapse

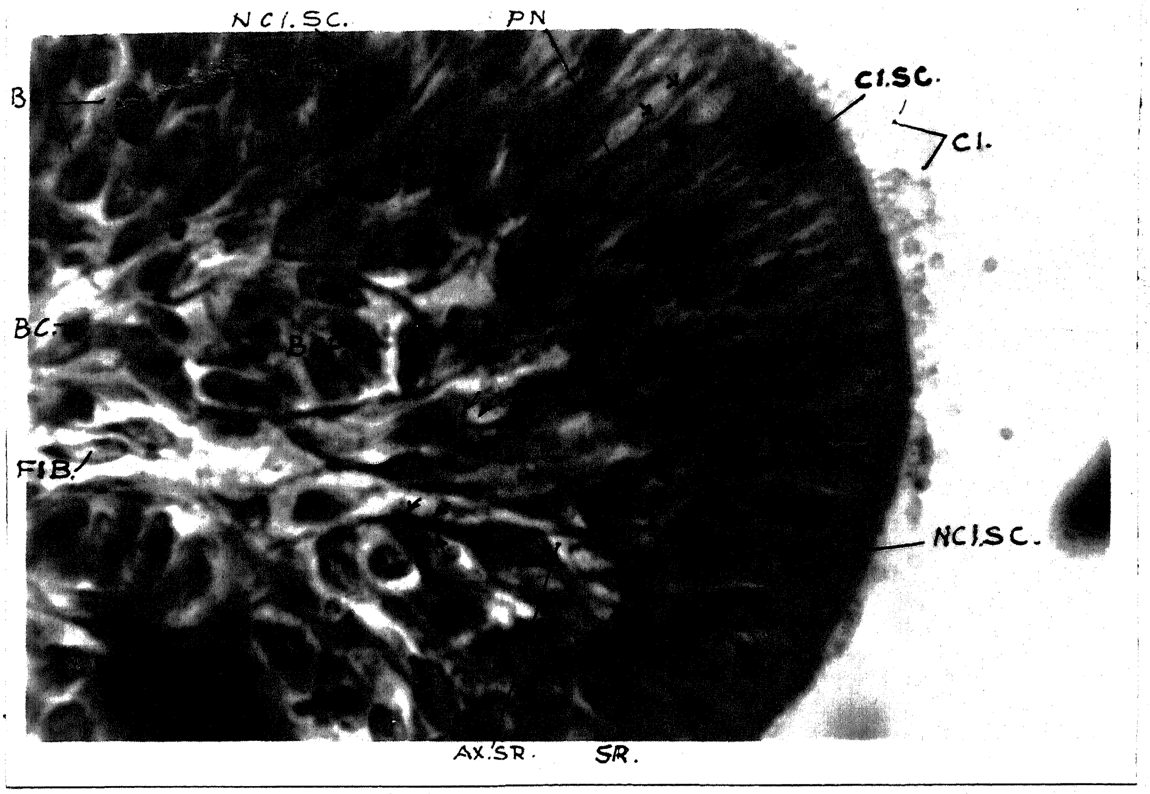


PLATE - 53

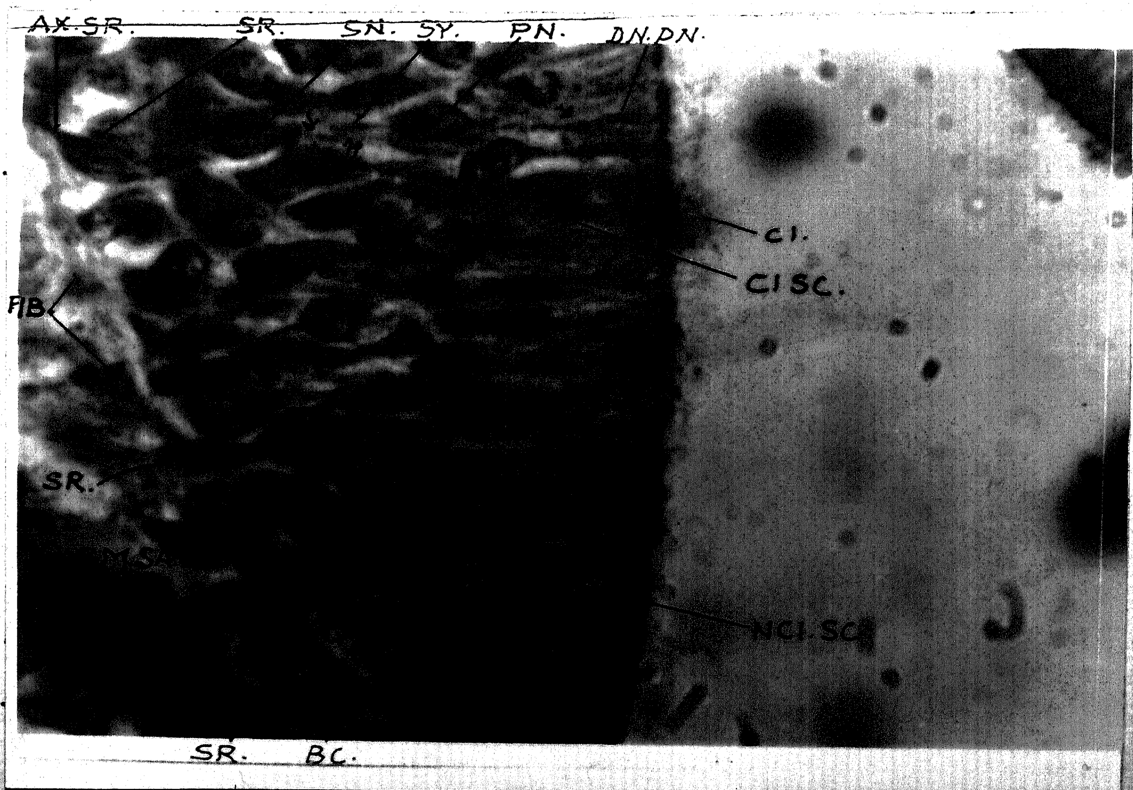


PLATE - 54

SR) are very conspicuous as these cells are present close to the basement membrane(BM) and are tightly packed with basal cells(BC). The nucleus is centrally located with uniform chromatin material(PL 45,52.53,54,55,56).

The Goblet Cells:

The goblet cells(GC) are very scantly supplied in the mucosa (MSA)of Anabas testudineus, but their presences cannot be denied(PL 51). The mucus content secreted by these goblet cells also entangles the foreign particles in the inter lamellar space(INT.LAM.SP) which are collectively removed out by the outgoing water.

In the accessory sac of this fish, large number of neck less goblet cells are found scattered among cuboidal supporting cells. In the sac the goblet cells(GC) are produced in large number at some places and forms tree like projections(PL 57,59). The mucous secretory goblet cells in the accessory nasal sacs of this fish are the resultant of muciferous activity of the cuboidal supporting cells(CU.SC). The goblet cells are oblong in shape, having conspicuous theca, with the nuclear content compressed downwardly in

the form of triangular mass. In the lachrymal accessory nasal sac(LAC.ACC.NAS.SAC), these cells are uniformly distributed but in the ethmoidal (ETH.ACC.NAS.SAC) one they are enormously or irregularly supplied(PL 57,58,59,60).

The basal cells:

In the olfactory epithelium of rosette(RE) basal cells(BC) are found arranged above the basement membrane(BM) in three to four layers. Thus lower portion of the mucosa (MSA)is occupied by the basal cells(BC, PL 45,48,49) . These are rounded cell body with a centrally placed nucleus, in which chromatin material are not visible, as these cells are always in transtionary stage. Their nuclei are the smallest found among the sensory epithelium. The nuclei is generally circular(PL 52,53,54,56). The basal cells (BC) are the mother cells which give rise to other cells. The basal cells(BC) are present in large number at the inter lamellar junction and in the secondary lamellae(SEC.LAM). These cells aggregates and forms hillock elevation(ELE.) which give rise to new lamellae(MINL,PL 42,44) . The formation of secondary lamellae is total effect of morphogenetic activity in basal cells(BC)which multiply

rapidly and under the pressure of excess production of basal cells(BC) they migrate to definite direction causing filiform, fungiform and cuneiform secondary lamellae on the surface of primary lamella(PR.LAM) which is also supplied with lymphatic space, which are some specific lamellae of the rosette.

In the accessory nasal sac the distribution of basal cells is to a considerable extent while in submucosa few cells are reported.

The central core or submucosa:

The central core (SMSA)of the lamellae can be easily identified , as it is lined by olfactory epithelium on either side. The submucosa(SMSA) is a ground substance for the olfactory structure, which provides a medium for the supply of nervous, vascular, nutritional and connective tissues to the mucosa. The central core(SMSA) of the lamellae are supplied with small branch of internal carotid artery, internal juglar vein and juglar lymphatic trunk which supplies lymph. In the olfactory epithelium of <u>Anabas</u> <u>testudineus</u> besides nervous and vascular supply, the connective tissue system also

Plate-55 High power magnification of mucosa and submucosa of *A. testudineus* showing their composition. Magnification x 100.

Plate 56 High power magnification of two lamellae angle zone along with bulk of floor of olfactory epithelium showing cellular composition, Arrow indicates synapse establishment between primary neuron and secondary neuron. Cylinder, solitary dendrite of spindle shaped receptor is visible. Magnification x1000.

AX.SR	Axon of spindle shaped receptor cell
BM	Basement membrane
BC	Basal cell
BCP	Blood capillaries
BCZ	Basal zone
CON.TIS. FIB	Connective tissue fibers
CI.SC	Ciliated supporting cell
DN.SR	Dendrite of spindle shaped receptor cells
FI.OL	Folium olfactorium
FIB	Fibroblast
HIS	Histocytes
LYM	Lymph space
NCI.SC	Nonciliated supporting cell
PN	Neuron
SR	Spindle shaped receptor cell
SMSA	Submucosa
SN	Secondary neuron
SY	Synapse
SCZ	Supporting cell zone

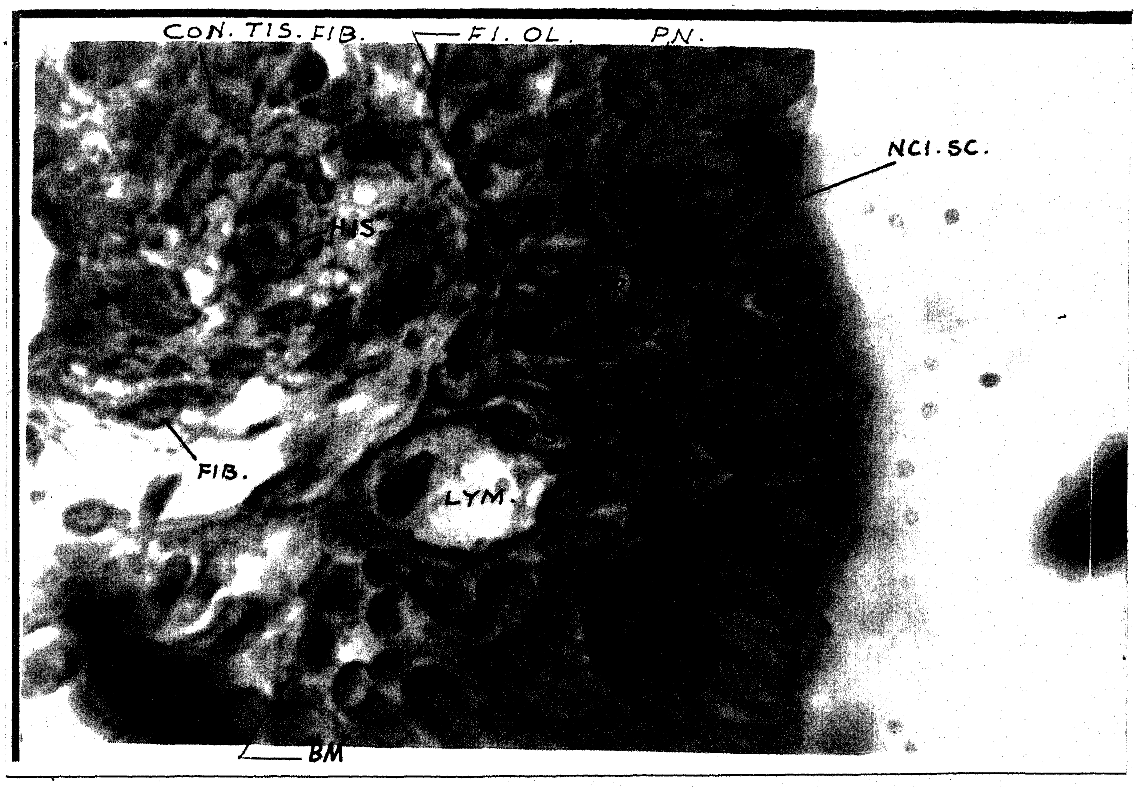


PLATE - 55

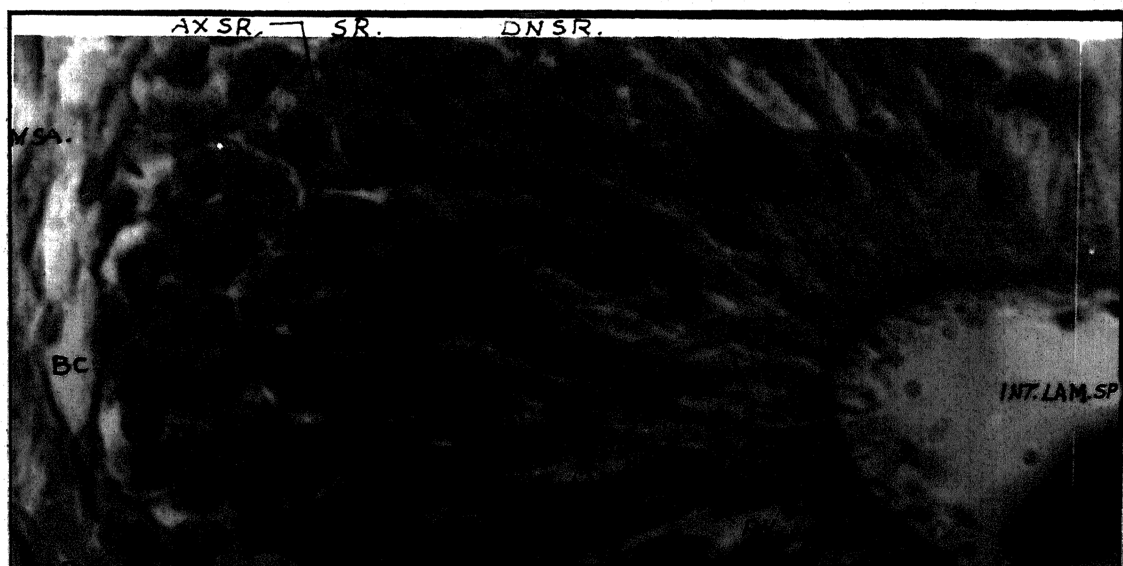


PLATE - 56

contributes in the formation of protective and supporting device .

In the submucosa (SMSA) of the lamellae collagen connective tissue fibers(CON.TIS.FIB.) are present, while in the accessory nasal sac elastic connective tissues are the main constituent. The submucosa in lamellar region is supplied with fibroblast(FIB) and adipose cells, where as histocytes (HIS), mast cells, lymphocytes and some plasma cells contributes the bulk of wandering cells. The fibroblast cells(FIB) are found lying among and upon the bundles of fibers. The fibroblast are usually elongated and flattened cells with oval nucleus. The formation and maintenance of collagen connective tissue fibers(CON.TIS.FIB) is based on these cells(PL 45,46,51,52,53,56)

In submucosa (SMSA) of these lamellae the blood supply(BCP) is very frequent are seen regularly distributed all along the basement membrane(BM). The folium olfactorium (FI.OL) collectively join to the nonmedullated nerve fiber (NMN.FIB) of the olfactory chamber(PL 46,51,52,55).

In the entire primary lamellae(PR LAM) the width of submucosa (SMSA) almost remain constant, but after the development of secondary lamellae(SEC LAM), basement membrane(BM) becomes wavy , as submucosa sends out its off shoots to the cellular content at each secondary lamellae(SEC.LAM), as a result of which lymphatic(LYM) and intercellular spaces occurs in it(PL 45,46,47,48) . In the submucosa of secondary lamellae (SEC.LAM) the macrophages and lymphoid wandering cells are found scattered. Besides this, prominent blood capillaries(BCP) are also present indicating intense cellular activity of these places. The central core or submucosa(SMSA) is devoid of sensory(RC), supporting(SC) and goblet cells(GC).

The accessory sacs:

In Anabas testudineus a pair of accessory sacs are found called ethmoidal (ETH. ACC.NAS.SAC)and lachrymal accessory nasal sacs(LAC.ACC.NAS.SAC, PL 40) . These sacs are attached to olfactory chamber and are histologically similar. The ethmoidal sacs(ETH. ACC.NAS. SAC) are long, mediodorsal sac lying slightly above the main olfactory chamber(PL57),while the lacrymal sacs(LAC.

ACC.NAS. SAC) are small narrow and extends upto the greater length of the maxillaries(PL 58). Both the accessory sacs are provided with cuboidal, highly secretary non sensory mucosa(MSA), which is supported by submucosa(SMSA), made up of elastic connective tissue fibre(CON.TIS.FIB) and richly supplied with blood capillaries(BCP), fibroblast cells(FIB), histocytes(HIS), mast cell and pigment cells(PIG, PL 57,58,60).

The ethmoidal sac(ETH.ACC.NAS.SAC.) is made up of more accumulated cells in mucosa, which takes the shape of minor elevation (EL)and depressions(DEP, PL 59) . This sac consist of major bulk of supporting zone(SCZ) fully packed with mucus secretory goblet cells(GC) and non ciliated cuboidal supporting cells(CU.SC), below which layers of basal cells(BC) are present. The basement membrane (BM)is densely wavy and demarcates submucosal zone(SMSA), which is filled with elastic connective tissue fibers (CON.TIS.FIB)and other cellular content(PL 57,59).

The lachrymal accessory nasal sac(LAC.ACC . NAS. SAC), is provided with more or less uniform mucosal zone (MSA)which is demarcated from the submucosa by

Plate-57 Vertical section of rosette of A.testudineus showing relation of ethmoidal accessory nasal sac with olfactory chamber. Magnification x 100

Plate 58 Vertical section of rosette of A. testudineus showing relation of lacrymal accessory nasal sac with olfactory chamber Magnification x 100

BCP	Blood capillaries
CON.TIS.FIB	Connective tissue fibers
ETH.ACC.NAS.SAC	Ethmoidal accessory nasal sac
FI.OLF.CH	Floor of olfactory chamber
INT.LAM.SP	Inter lamellar space
LAM	Lamella
LAC.ACC.SAC	Lacrymal accessory nasal sac
MSA	Mucosa
NMN.FIB	Non medullate nerve fiber
SMSA	Submucosa

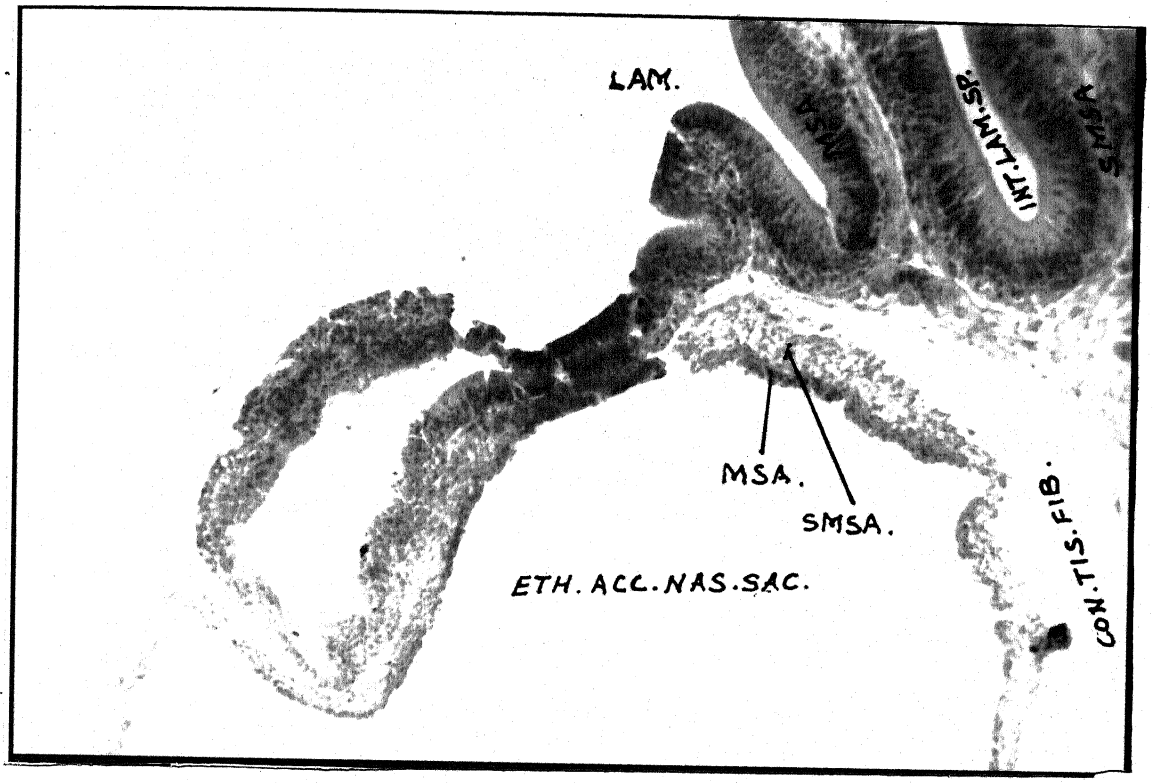


PLATE - 57

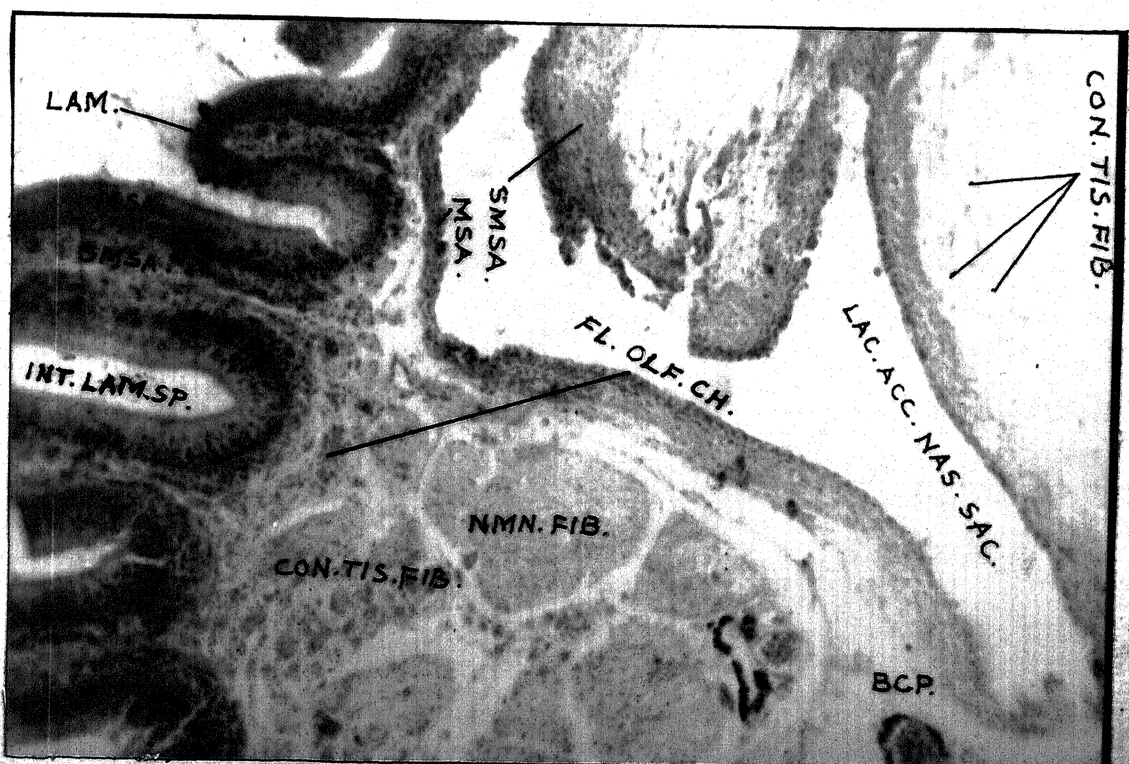


PLATE - 58

Plate-59 Vertical section of ethmodial accessory nasal sac of A. testudineus showing cellular composition of its mucosa and submucosa. Magnification x 400

Plate 60 Vertical section of lacrymal accessory nasal sac of A. testudineus showing cellular composition of its mucosa and submucosa. Magnification x 400

BCZ	Basal cell zone
BC	Basal cell
BM	Basement membrane
CU.SC	Cuboidal supporting cell
CON.TIS.FIB	Connective tissue fibers
DEP	Deepening
EL	Elevation
FIB	Fibroblast cell
GC	Goblet cell
HIS	Histocytes
MSA	Mucosa
SMSA.	Submucosa
SCZ	Supporting cell zone.

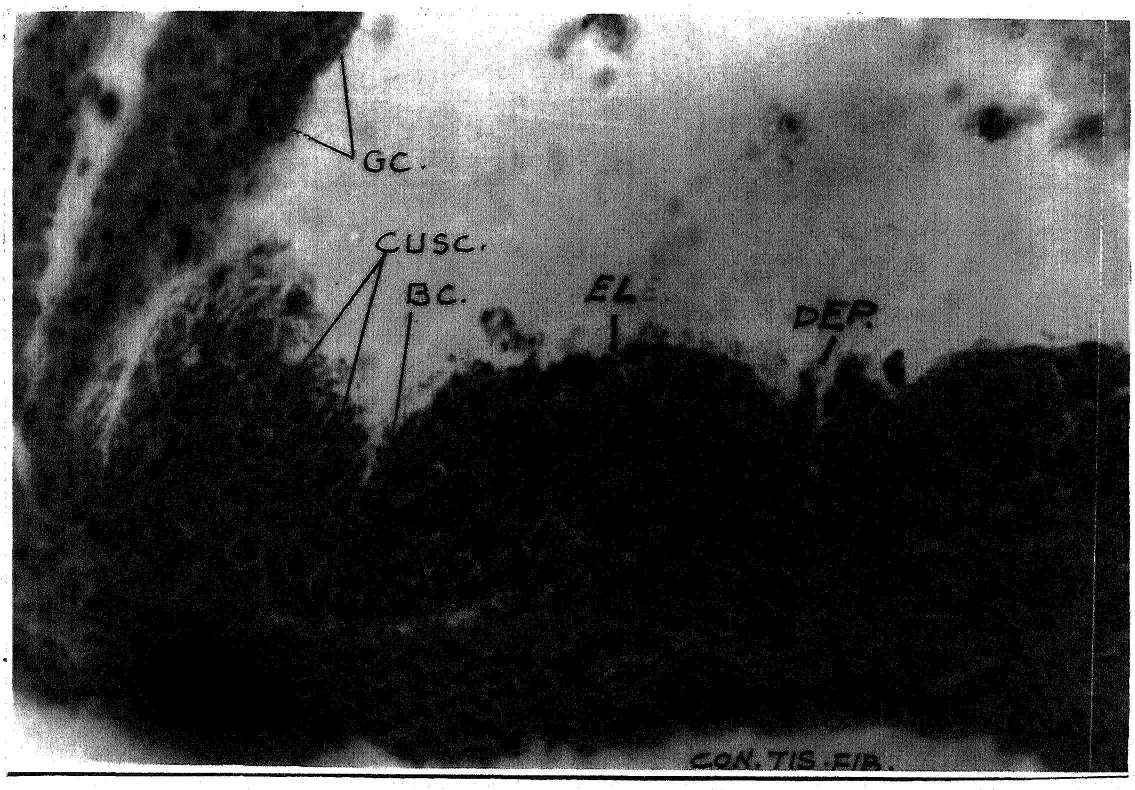


PLATE - 59

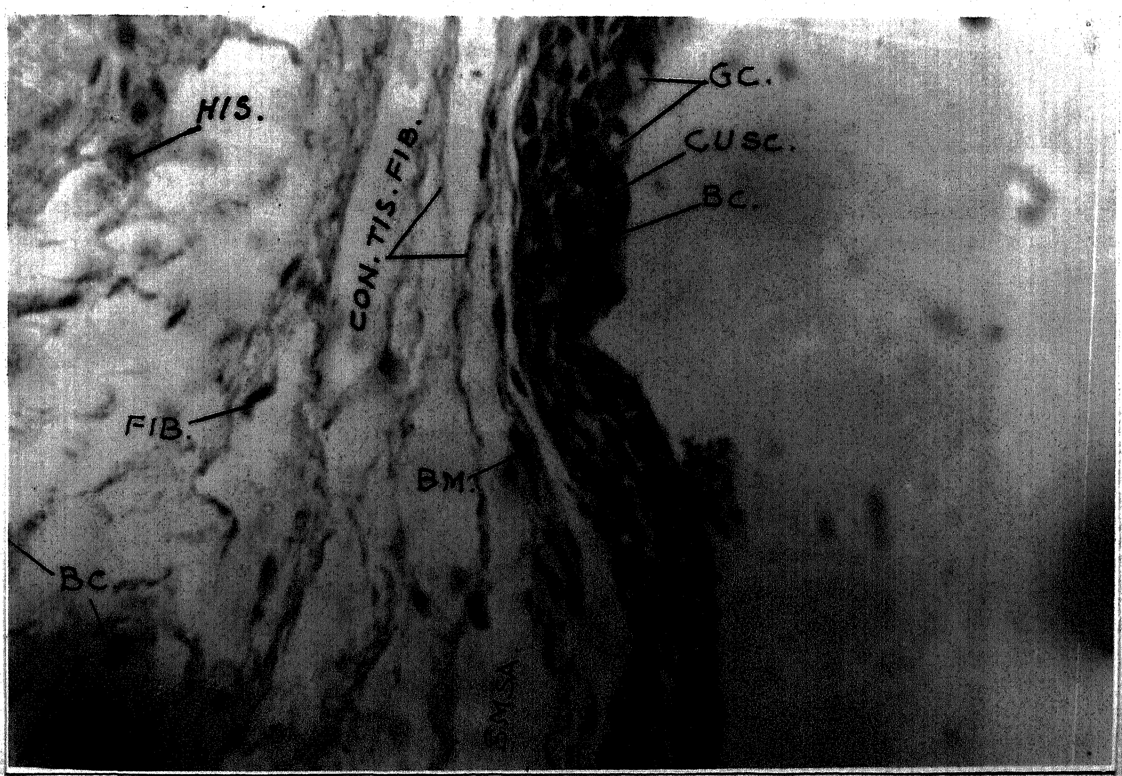


PLATE - 60

uniformly encircling basement membrane. The submucosa (SMSA) of this sac is made up of equally distributed elastic connective tissue (CON.TIS.FIB)along with fibroblast(FIB), histocytes(HIS), basal cells(BC) and mast cells. The pigment cells (PIG)are also visible in this zone. The muciferous activity in the supporting zone of lachrymal accessory nasal sac (LAC.ACC.NAS.SAC) is so acute that out pushing of secretary accumulation is seen(PL 58,60) .

Both the ethmoidal and lachrymal sacs are flexible and act as a secretory organ and produced mucus, which is important in cleaning the nasal sacs and in keeping the olfactory epithelium healthy and highly sensitive. Both the accessory nasal sacs remain communicated to olfactory chamber through posterior nasal opening.

The unidirectional flow of water:

In Anabas testudineus the movement of water in the olfactory chamber is undoubtedly brought about by the ciliary (CI) action of supporting cells (SC), by the movement of posterior nasal barbel and due to the contraction and relaxation of elastic connective tissue fibers(CON.TIS.FIB) of both the accessory nasal sacs. Besides this, the upper jaw

of *Anabas testudineus* is slightly protusible whose movement also modifies the volume of the ethomoidal sac, because during maximal opening of jaws maximum expansion of the accessory sac can only take place.

Experiment in live *Anabas testudineus* with chalk particles proof that water is sucked in by the anterior nasal pore(ANT.NAS.OP) and expelled by the posterior pore(POST.NAS.OP, PL 39) , showing unidirectional flow of water. Due to the continuous synchronous movement of cilia and posterior barbel, the water current enters into the olfactory chamber through anterior nasal pore and passes into the accessory nasal sacs. Here the water is retain for longer period, and is pumped again and again for proper bathing of lamellae. The water circulating over olfactory rosette(RE) is free from mud and foreign particles, as they are trapped by mucus secreted by the goblet cells(GC) of the accessory sacs. After circulation over rosette, the water goes out from olfactory chamber(OLF.CH) through posterior nasal pore(POST.NAS.OP) . The out going water current, carries away mud and foreign particles out of the olfactory chamber and thus clean the olfactory passage.

Histoecological variations:

In Anabas testudineus only seven to ten lamellae(LAM) are found. So to cope up with diverse condition each lamellae in itself act as a single rosette. Each lamellae has a composite structure and the periphery is provided with number of hillock elevations(ELE). These elevations ultimately give rise to cueniform , filiform and fungiform secondary lamellae(SEC.LAM, PL 45, 46,47,48) and increase its surface area. The secondary lamellae show intense cellular activity, as they are provided with submucosal offshoot, macrophages cells and lymphoid wandering cells.

In Anabas testudineus the number of lamellae are less hence for the smooth physiological activity this fish develops secondary lamellae (SEC.LAM). The formation of a secondary lamellae is a slow and sequential process. In young fish most of the primary lamellae(PR.LAM) are covered by receptors and supporting cells and of two layer basal zone. As the fish becomes adult the central core projects out few offshoot towards the periphery, almost at equal distance. There may be an inter play between

organization in a blood capillary(BCP) in the central core and the olfactory epithelium, in the epithelial lining, soon small outgrowths occur, as the cells of the mucosa(MSA) above the dermal offshoot undergoes rapid multiplication resulting diminutive outgrowths as the initiation of formation secondary lamellae. These secondary lamellae mainly consist of undifferentiated cells. Thus the superficial cells between the two initial secondary lamellae appear to be sunken(FIG. A).

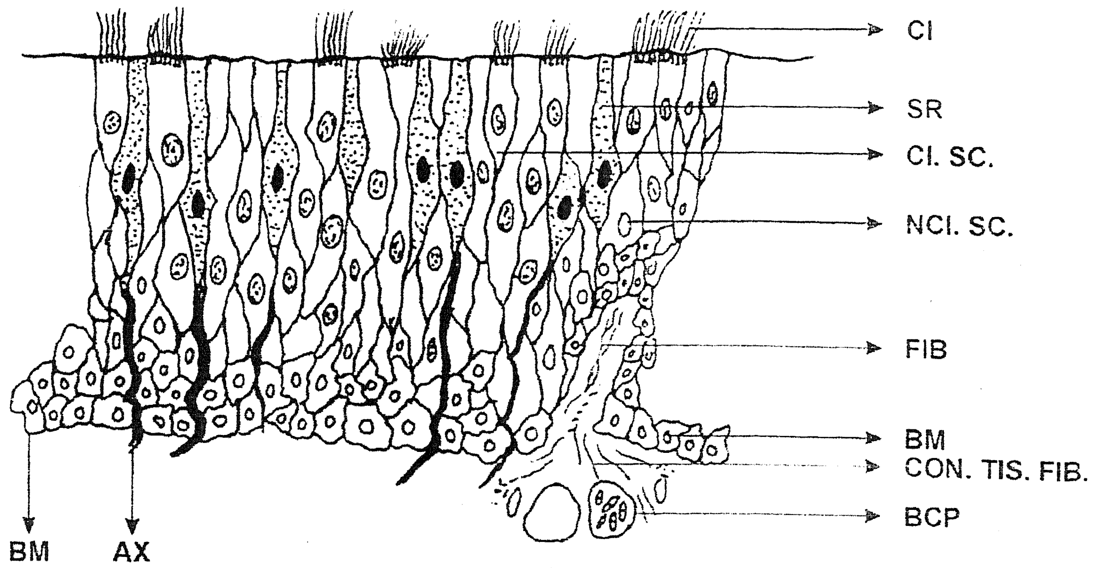
In the development of secondary lamellae(SEC LAM), the second stage consists of formation of cuneiform secondary lamellae. In this stage due to further penetration in the submucosa (SMSA), the undifferentiated cells get pushed outwards. Through rapid multiplication, the initial secondary lamellae becomes prominent and wedge shaped or cuneiform. The cells of the transtionary epithelium(TRAN EPI) are prominent and show various stages of cell division. The nuclei are circular and lie superficially and like those present in the depressions where the elongated nuclei of the sensory cells are located quite away form the surface of the cells.(FIG.B)

In the third stage the differentiation of uniform lamellae into filiform lamellae take place. This stage is characterized by the appearance of lymph spaces(LYM) in the head of the secondary lamellae. In this stage few fibroblast(FIB), mesenchymal, reticular (RET C) and blastema cells (BL), along with blood capillaries(BCP) are also seen scattered. The depressions turn into deep valleys as the filiform lamellae protrude out. (FIG.C)

In the final stage of development, the filiform secondary lamellae become broad and fungi form. The greater part of the secondary lamellae(SEC LAM) are now occupied by both lymph(LYM) and inter cellular spaces(INT LAM SP). On the margin of head and neck of the fungiform lamellae, only a thin boundary of undifferentiated cells is present. The reticular tissues of the central core often penetrates up to the neck of the fungiform lamellae. The turger of this keeps the neck more rigid than flexible head(FIG D).

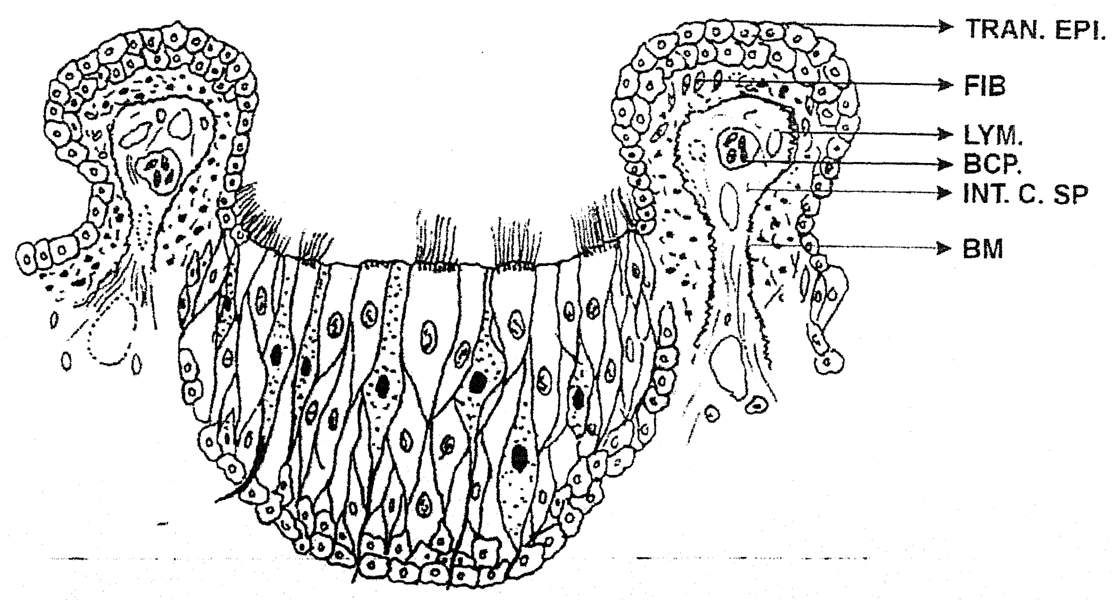
It is found that each secondary lamellae(SEC LAM) are physiologically active as the submucosa(SMSA) of Anabas testudineus is richly supplied with blood vessels in these

Initial Secondary Lamellae



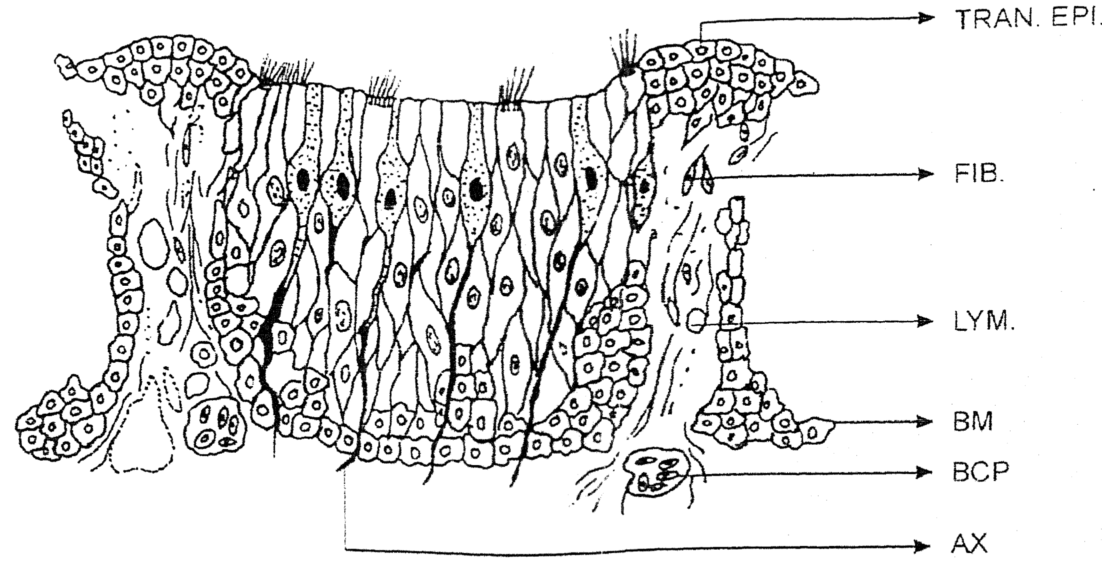
Submucosal contents starts migrating to the periphery and the mucosal zone above this off shoot cells are multiplying rapidly resulting in dimunative outgrowth.

Fungiform Secondary Lamellae



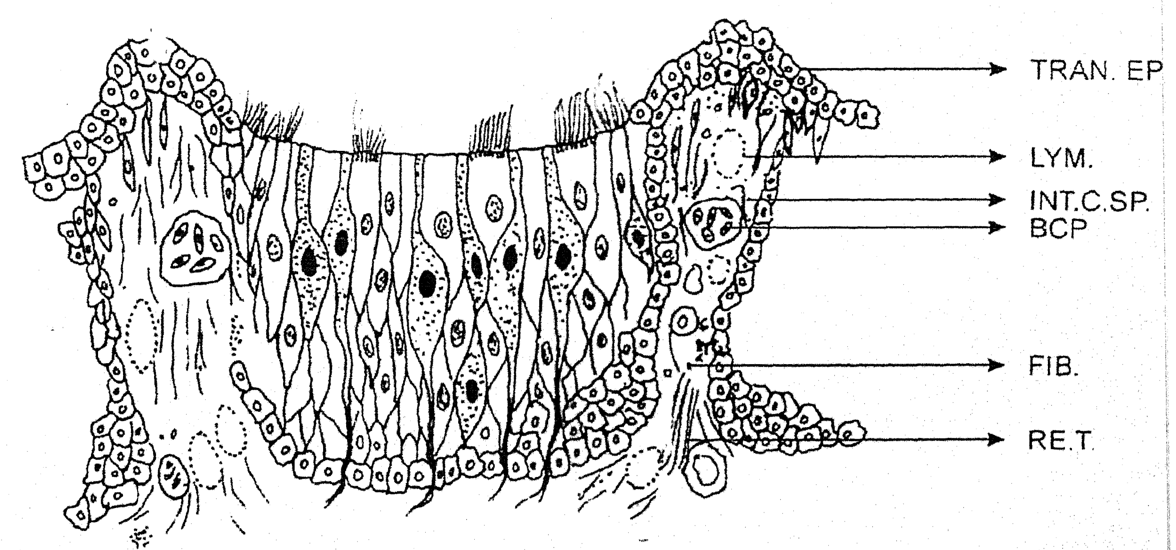
Filiform secondary lamellae become broad and changing into fungiform. Submucosal contents are clearly visible and penetrating upto the neck of fungiform lamellae into inter lamellar space on the surface of the mucosa.

Cuneiform Secondary Lamellae



Deep penetration of submucosa pushing the content outward, as a result the initial secondary lamella becomes wedge shaped or cuneiform. The c of transtionary epithelium is showing various stages of cell division.

Filiform Secondary Lamellae



Lymph space appears in the head of the secondary lamellae and mesenchymal, fibroblast, reticular, blastema cell along with blood capillaries turning lamellae into deep valley as filiform, causing enhancement in all receptory surface.

A Diagrammatic Representation Of Formation Of Secondary Lamellae

formations. Except this, the fish also consist of well developed accessory sacs, which controls the exit and entry of water during snapping, yawning and respiration. As Anabas testudineus has a sedentary habit, accessory nasal sacs plays important role for olfactory reception and also allow to clean the olfactory passage . Anabas testudineus is a predatory fish leading most active life and this is in accordance with the presences of secondary lamellae and well developed accessory nasal sac which allows it to be more promptly and accurately responding to environmental changes .

Ecological coefficient of <u>Anabas</u> <u>testudineus</u>:

Ecological coefficient was calculated by two methods: First by taking the length of mesencephalon and telen cephalon as parameter; second by measuring the area of both the rosette and retina. The effectiveness of the olfactory and optic faculties was assessed approximately by comparing the former and latter parameter.

For calculating the ecological coefficient , five fishes of different sizes ranging form 74.5mm to 115mm of total length were selected. It was observed that the length of brain and the number of lamellae increase successively with the size of the fish. The length of mesencephalon ranges from 2.05 mm to 2.65mm and telencephalon from 3.27mm to 5.05mm. The ecological coefficient ranges from 141.37 to 190.56 percent.

The area of both the retina and rosette were measured by the usual methods. It was observed that the former ranges from 65.50mm^2 to 78.00 mm^2 where as the latter from 75.00 mm^2 to 90 mm^2 showing ecological coefficient range from 101.55 mm^2 to 115.70 mm^2 percent (Table 2) . The

result thus obtained shows that Anabas testudineus is a 'mesosmatic fish' because it possesses both olfactory and optic faculties which suits to its surface feeding habit.

Table 2 Ecological coefficient of <u>Anabas testudineus</u>

S. No	Stand length mm	No. of Lamellae Right Left	Total length of Brain mm	Length of Mesencephalon mm	Length of Telencephalon mm	Ecological coefficient =length of telen x 100 / Mesen	Retinal Area of Both Eyes mm^2	Olfactory Area of both Rosette mm^2	Ecological Coefficient= Olfactory area x100 / Retinal Area
1	74.5	7 8	7.29	2.05	3.27	159.5	65.50	75.00	114.50
2	90.5	8 8	9,88	2.90	4.10	141.37	78.02	78.02	104.02
3	95.0	8 9	9.50	3.00	4.85	161.66	77.00	78.20	101.55
4	115.0	9 9	9.47	2.50	4.09	163.60	77.00	83.12	107.94
5	120.0	10 10	10.0	2.65	5.05	190.56	78.00	90.25	115.70
						163.34			108.74

Plate-61 Dorso lateral photograph of M.aculeatus showing rostral appendage and the position of anterior and posterior nasal openings.

Plate 62 Dorso lateral photograph of M.aculeatus showing position of rosette, its relation with brain and infra nasal chamber.

ANA.NAS.OP	Anterior nasal opening
EY	Eye
INF.NAS.CH	Infra nasal chamber
OLF.NE	Olfactory nerve
OLF.LO	Olfactory lobe
OP.LO	Optic lobe
RE	Rosette
ROST.APP	Rostral appendage
POST.NAS.OP	Posterior nasal opening

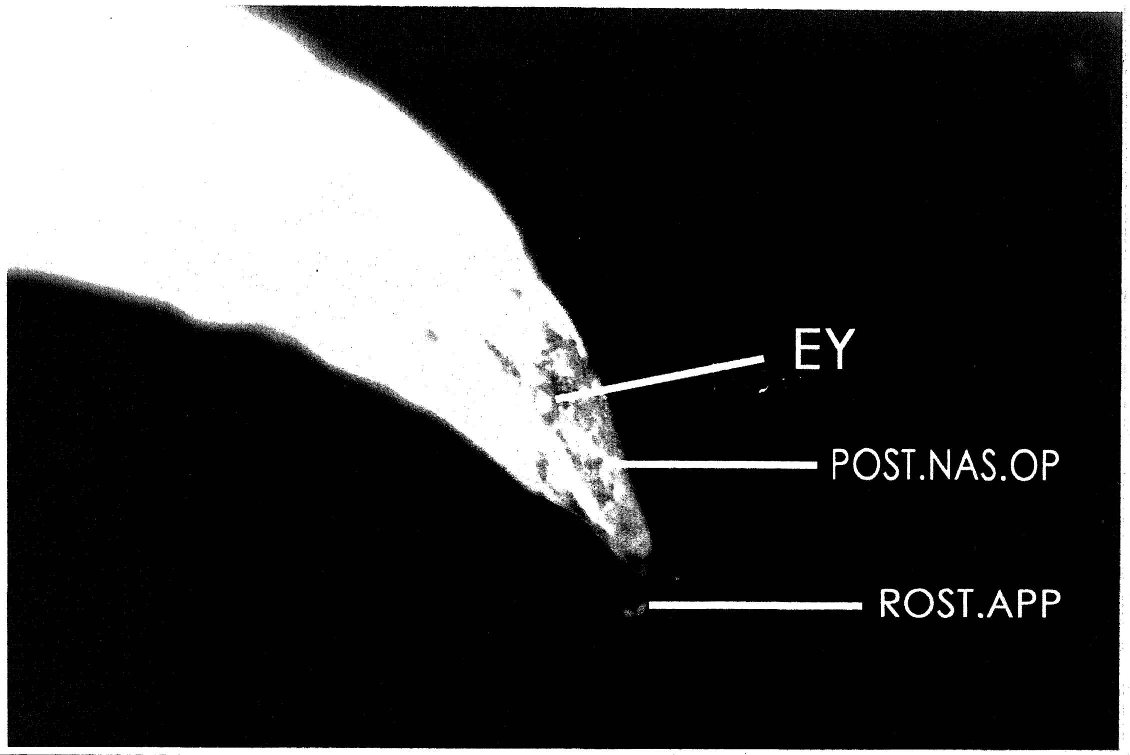


PLATE - 61

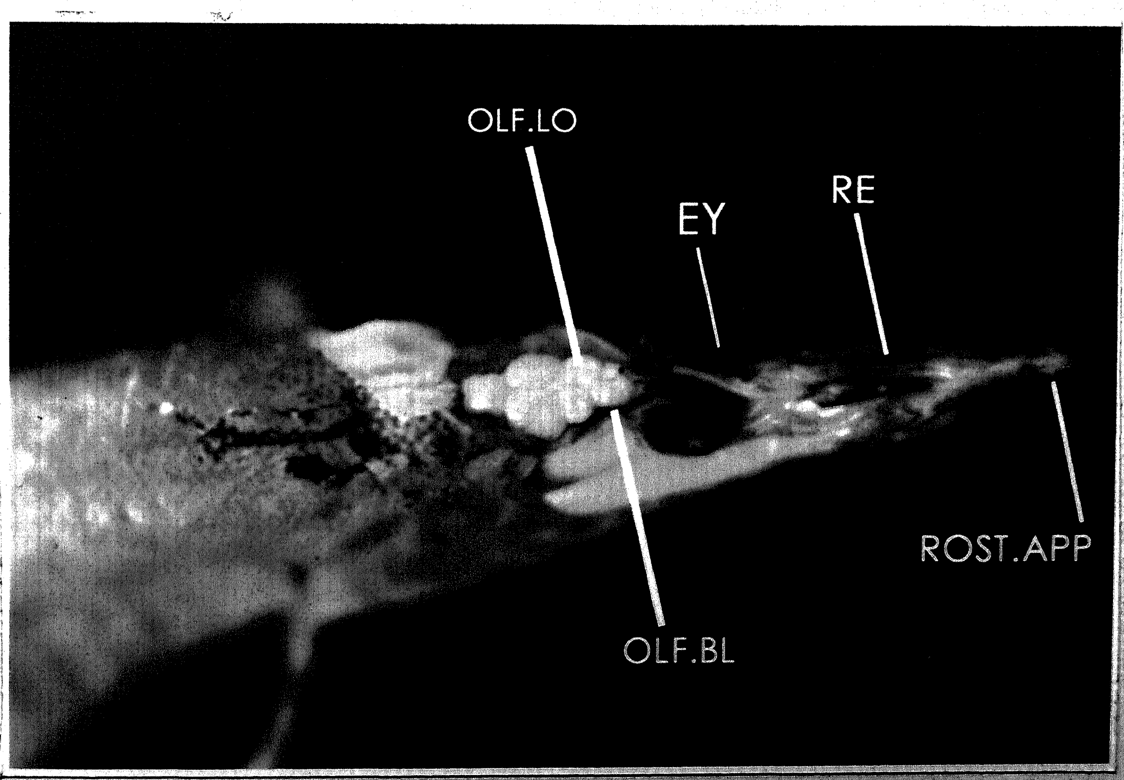


PLATE - 62

HISTOLOGICAL OBSERVATION OF Macrognathus aculeatus

The olfactory chamber of Macrognathus aculeatus enormously developed occupying the entire dorsa lateral surface of the head. The olfactory chamber in this fish is found posteriorly broader, while it gradually tapers towards the anterior side. The chamber communicates outside by a pair of nasal openings, which are designated as the anterior(ANT.NAS.OP) and posterior nasal openings (POST.NAS.OP,PL 61) by the virtue of their respective positions in head. The anterior nasal opening are tubular and opens on either side of fleshy rostral appendage(ROST APP, PL 62). The anterior part of the tubular nasal opening (ANT.NAS.OP) along with the thin covering of integument forms the tentacle like structure, which in natural condition is directed downward and forward. The posterior nasal opening(POST.NAS.OP) lies in front of and ventrally to the eye orbit, which is demarcated by an area lined by a loose integument. It is a slit like opening constituted by ventral and dorsal lip and lies just above the cresentric aperture of infra nasal chamber(INF.NAS.CH, PL 61). In the fish of 250mm of total length the anterior and posterior nasal opening are found lying at a distance of 12mm.

Plate-63	Dorso lateral photograph of M. aculeatus showing brain components olfactory nerve and its relation with rosette.
Plate 64	Vertical section of rosette of M. aculeatus passing through anterior accessory nasal sac and lamellar zone having pigment sheath all around.

EY	Eye
LAM	Lamellae
Lum	Lumen
OLF.NE	Olfactory nerve
OLF.LO	Olfactory lobe
OLF.BL	Olfactory bulb
OP.LO	Optic lobe
PIG.SH	Pigment sheath
POST	Posterior end
RE	Rosette
ROST.APP	Rostral appendage.

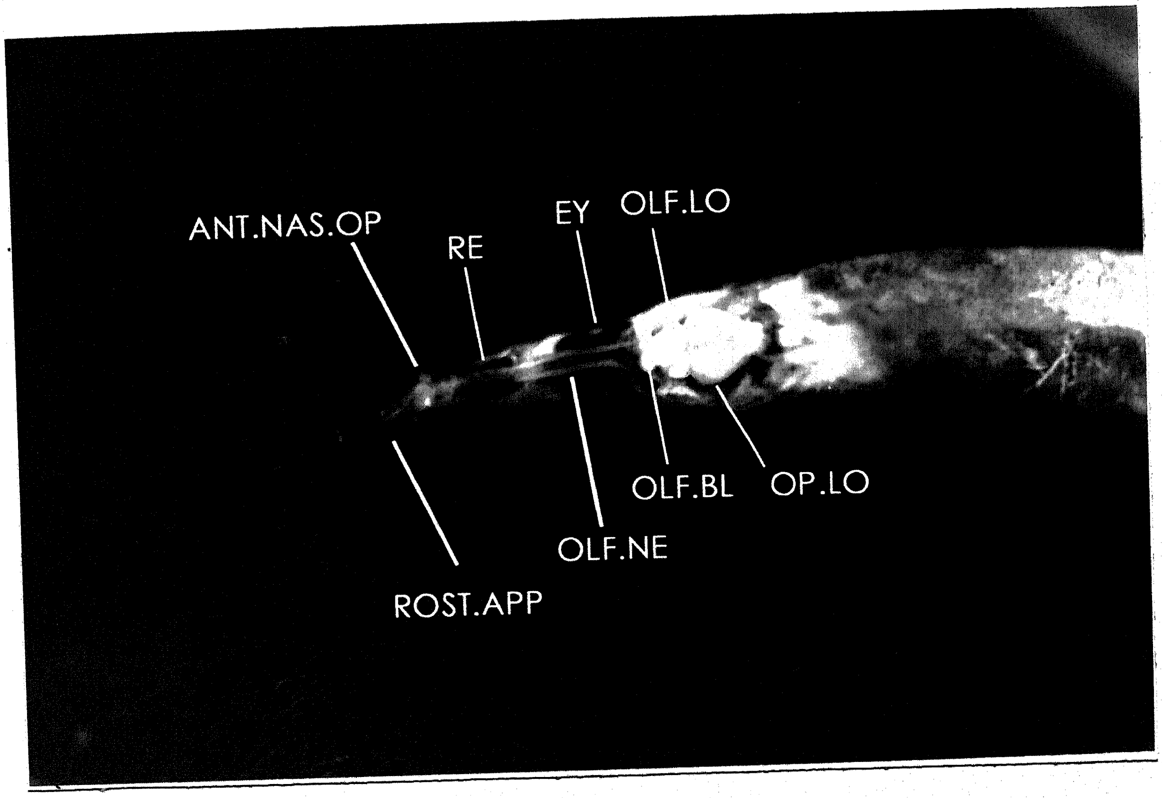


PLATE - 63

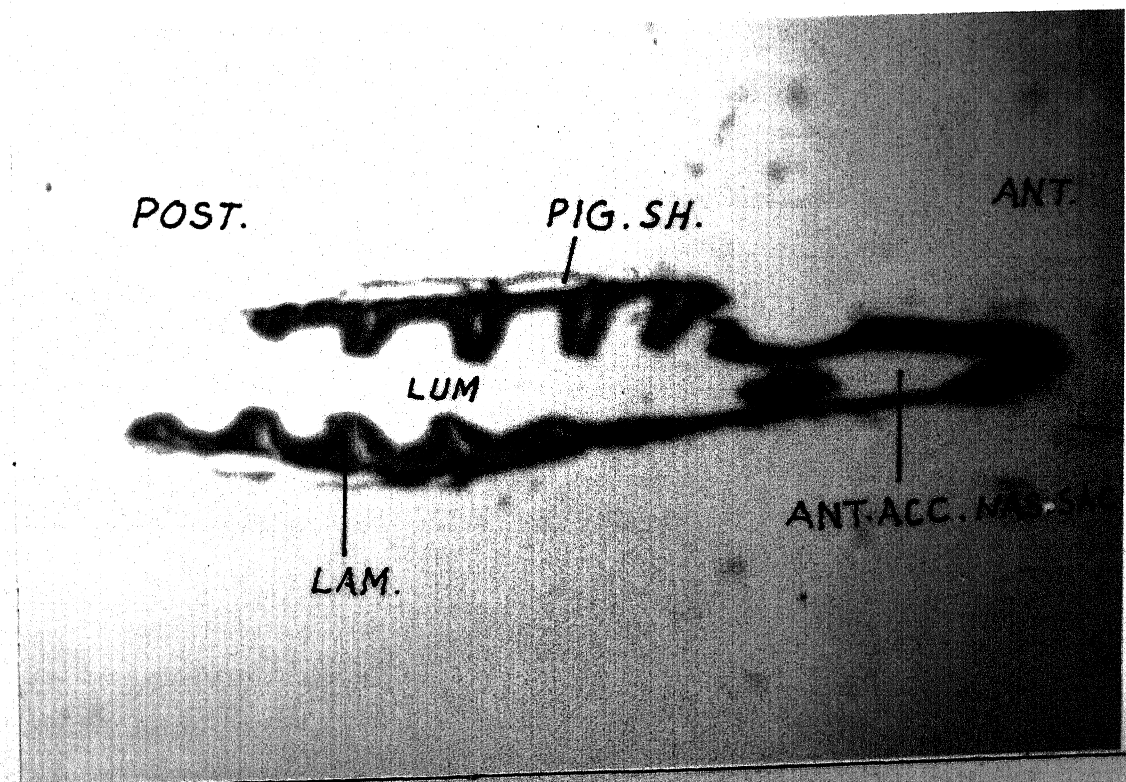


PLATE - 64

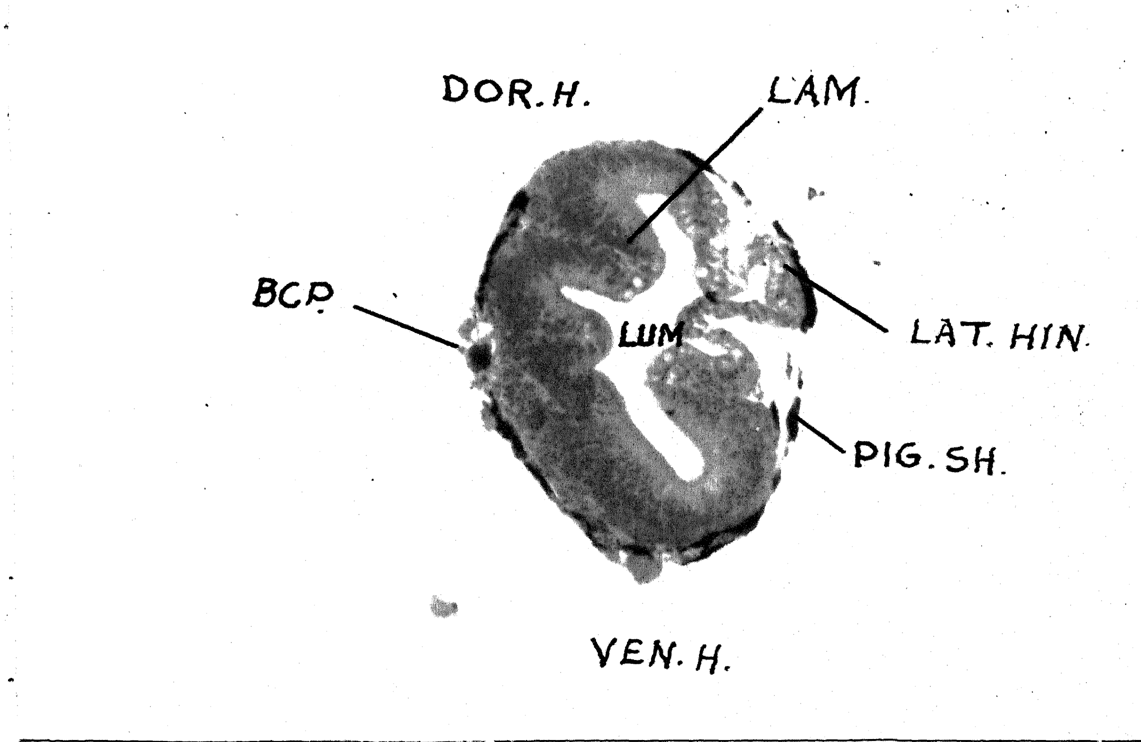


PLATE - 65

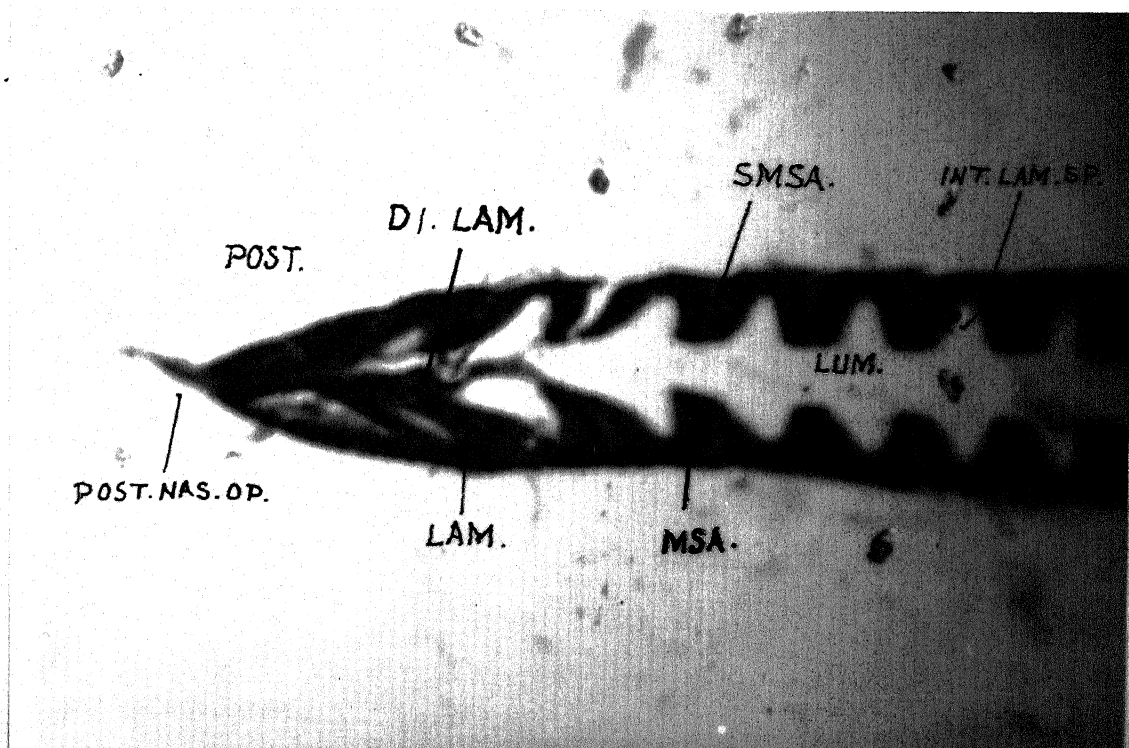


PLATE - 66

Plate-65 Transverse section of rosette of M. aculeatus showing orientation of dorsal and ventral halves with lateral hinges and lumen position. Pigment sheath all around is visible Magnification x 100.

Plate 66 Vertical section of rosette of M.aculeatus showing posterior elongated lamellae joining each other, forming obliterated zone and there after lumen extent to, anterior side having different type of lamellae on both its side. Magnification x 100.

BCP	Blood capillaries
DOR.H	Dorsal hinge
DI.LAM	Distal lamellae
INT.LAM.SP	Inter lamellar space
LAM	Lamellae
LUM	Lumen
LAT.HIN	Lateral hinge
MSA	Mucosa
PIG.SH	Pigment sheath
POST	Posterior end
POST.NAS.OP	Posterior nasal opening
SMSA	Submucosa
VEN.H	Ventral hinge

In the olfactory chambers of <u>Macrognathus</u> <u>aculeatus</u> a peculiar type of rosette (RE) is found. The olfactory rosette of this fish is barrel shaped (PL 62,63), which is made up of dorsal and ventral halves, joining each other by their lateral hinges(LAT.HIN, PL65). Both the halves from their respective surface give rise to number of folds or lamellae(LAM), which encloses a continuous central cavity called lumen(LUM, PL64,65,66). In <u>Macrognathus</u> <u>aculeatus</u> lamellae (LAM)are arranged in definite succession displaying three distinct order: in anterior part of the rosette lamellae have expanded tip ,while in middle part mixed and posteriorly they have pointed tips(PL 64,66).In each case the base are equally expanded maintaing inter lamellar spaces among them. In posterior region lamelllar extension is so acute that they meet with their terminal ending in the form of mucus secreted bridge ,obligating lumen(LUM) part of the rosette(PL 66,67).In every case a continous lumen is maintain anterioposterioly allowing free water circulation through lumen for bathing lamellae properly.

The infranasal chamber(INF.NAS.CH) is found lying ventrally to the olfactory rosette(RE) which extends posterio

anteriorly just below the lacrymal bone and act as a reservoir of water to irrigate the olfactory lamellae(PL 62). The olfactory rosette(RE) and infra nasal chamber(INF.NAS.CH) are found with elastic connective tissue fibers creating a synchronous compression and expansion in the sacs which regularly invites water current through chamber.

The olfactory rosette(RE) of Macrognathus aculeatus is surrounded by a thick dense connective tissue sheath which shows rich distribution of the pigment cells(PIG), giving it a dark black appearance. The blood and the nervous supply is also encircled independently by the pigment sheath(PIG, PL.64,65) The olfactory nerve(OLF NE) enters through the olfactory foramen and extends along the inner surface of the rosettes distributing its nerve fibers in between various folds or lamellae(LAM, PL62,63). The orbito nasal artery runs along the rosette and supply its branches to the lamellae(LAM) through the central core or submucosa of each lamellae, while the blood is collected form these region by orbito nasal vein thus submucosa(SMSA) of every lamellae is supplied by these blood vessels(BCP). In Macrognathus aculeatus the formation of secondary lamellae or other micro formations are not always visible.

Plate-67 Vertical section of rosette of M.aculeatus showing posterior obliteration of lamellae due to extended distal tip. Magnification x 100

Plate 68 Vertical section of lamella of M. aculeatus showing morphogenetic activity in submucosa sending mucosal cellular component to its periphery for prompt olfactory reception clear at cellular composition their pattern of arrangement in mucosa and submucosa is clearly visible. Arrow indicating dendritic and axonal extension to their respective zones.

BM	Basement membrane
BCZ	Basal cell zone
BCP	Blood capillaries
CI.SC	Ciliated supporting cell
CI	Cilia
DL.LAM	Distal lamellae
FI.OL	Folium olfactorium
INT.LAM.SP	Inter lamellar space
LUM	Lumen
MSA	Mucosa
MORP	Morphogenetic activity
OCI	Olfactory cilia
PN	Primary neuron
POST	Posterior side
PIG.SH	Pigment sheath
SMSA	Submucosa
SR	Spindle shaped receptor cells.

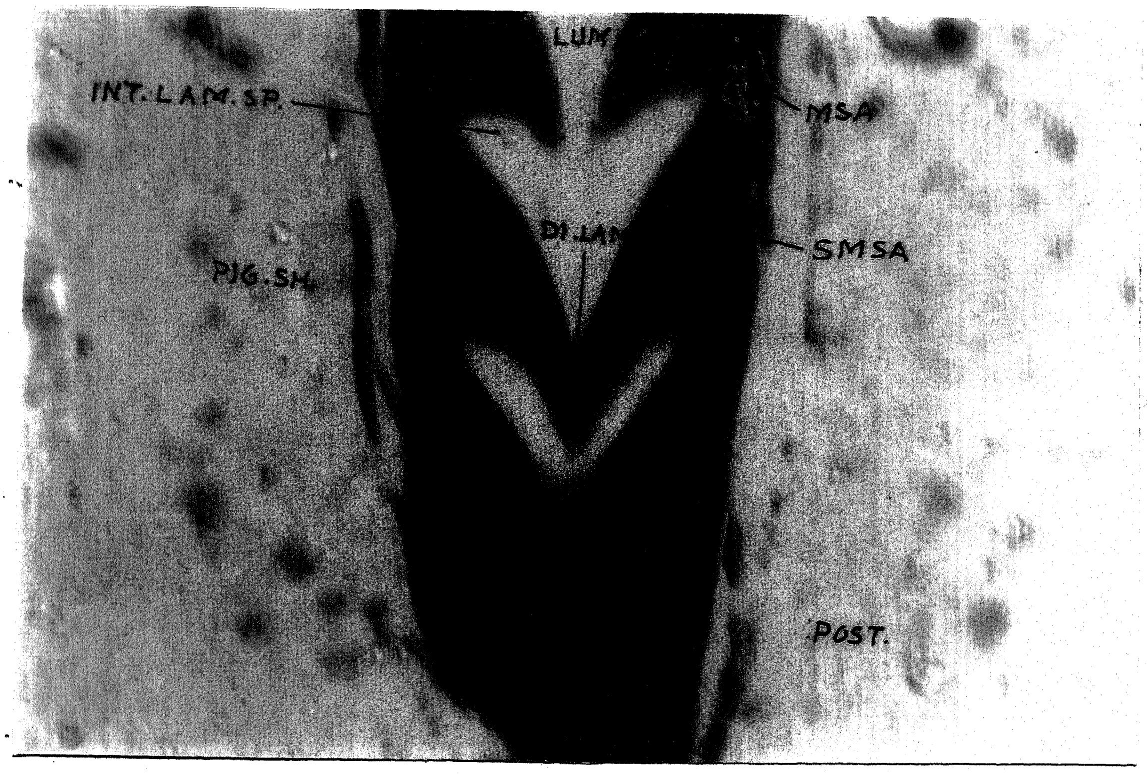


PLATE - 67

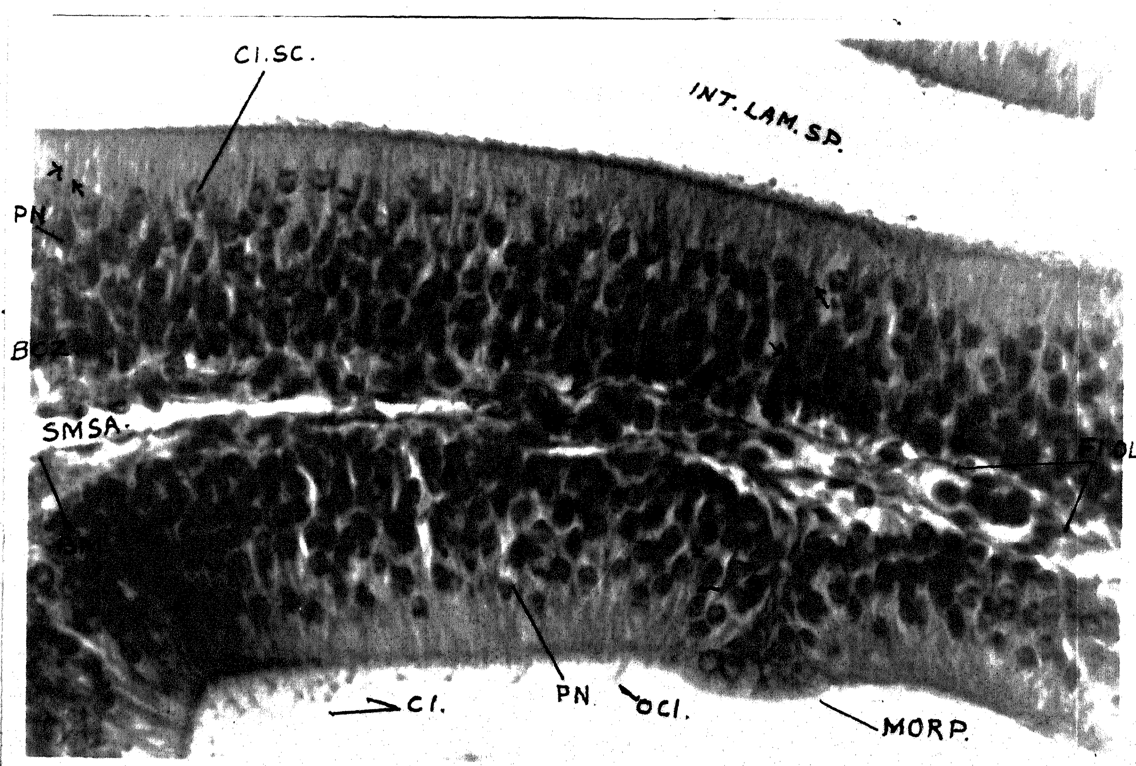


PLATE - 68

Occasionally submucosa(SMSA) of this fish exhibit morphogenetic activity(MORP, PL 68,74) causing flow of cellular contents towards the peripheral region of mucosa(MSA).

The olfactory epithelium of <u>Macrognathus</u> <u>aculeatus</u> is made up of compact cellular components of mucosa(MSA), which is separated by a central core or submucosa(SMSA), by a well defined basement membrane(BM). The olfactory epithelium of this fish is composed of following cells : supporting cells, receptor cells, goblet cells and basal cells.

The supporting cells:

In the olfactory epithelium of <u>Macrognathus</u> <u>aculeatus</u> the supporting cells are found compactly arranged in two successive rows, in such a manner that they allow the passage for dendrites(DN) of the receptor cells to its peripheral surface. The nucleus(NU) has thin, delicate outline with clearly visible nucleolus and chromatin material.(PL 69,70,73,74,75)

The supporting cells(SC) consist of a short and thick distal limb, ending on a peripheral surface by a convex side. The distal limb is filled with granular concentrated cytoplasm, which is more concentrated towards the convex end which bears cilia projecting into the interlamellar spaces(INT.LAM.SP, PL68,70,74). The row of supporting cells at the peripheral side with ciliated convex end can be demarcated as secondary supporting cells and the second row of non ciliated supporting cells(NCI.SC) can be called as primary supporting cells. In primary supporting cells (NCI.SC) the transitionary stages can be seen as they either transforms into the secondary supporting cells(CI.SC) or in mucus secretary goblet cells(GC). These cells can be confused with basal cells(BC)

The receptor cells:

These cells are abundantly supplied in the olfactory epithelium of <u>Macrognathus</u> <u>aculeatus</u> These cells are of two types: Primary neurons(PN) and Spindle shaped receptor cells(SR) lying at different depths.

Plate-69	Vertical section of lamellae of A. testudineus passing through middle and terminal zone showing grouping of primary neurons and total composition of submucosa and mucosa in relation to inter lamellar space and lumen of rosette. Magnification x 400
Plate -70	Vertical section of lamellae of A. testudineus passing through base, showing vascular, connective tissue, nervous supply to the lamellae. Mucosal and submucosal cellular composition prominent. Pigment sheath around base of lamellae is visible. Magnification x 400

AX.PN	Axon of primary neuron
BM	Basement membrane
BCP	Blood capillaries
BCZ	Basal cell zone
CI	Cilia
CI.SC	Ciliated supporting cell
DN.PN	Dendrite of primary neuron
DI.LAM	Distal lamellae
FI.OL	Folium olfactorium
GC	Goblet cell
GC.TH	Goblet cell theca
GR.PN	Grouping of primary neuron
GR.BC	Grouping of basal cell
INT.LAM.SP	Inter lamellar space
MSA	Mucosa
NCI.SC	Nonciliated supporting cell
NMN.FIB	Non medullated nerve fiber
OCI	Olfactory cilia
PIG.SH	Pigment sheath
PN	Primary neuron
PN.DN	Primary neuron dendrite
PN.AX	Primary neuron axon
SMSA	Submucosa
SR	Spindle shaped receptor cells.

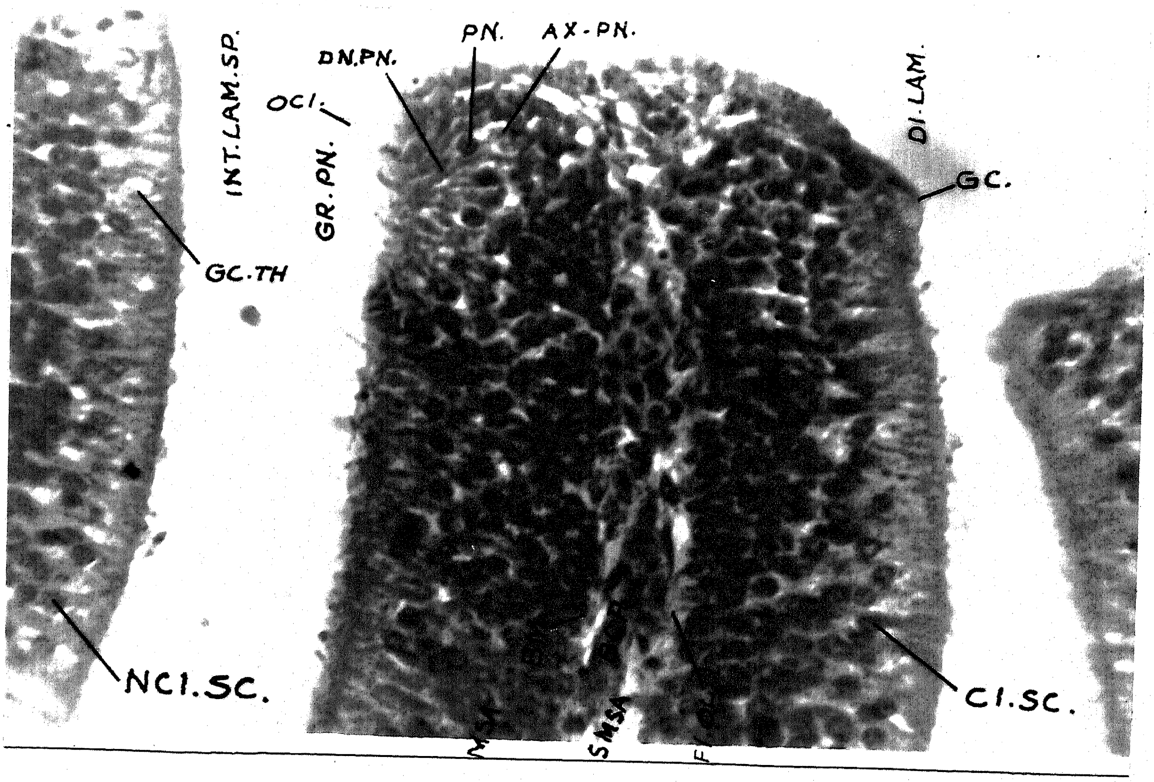


PLATE - 69

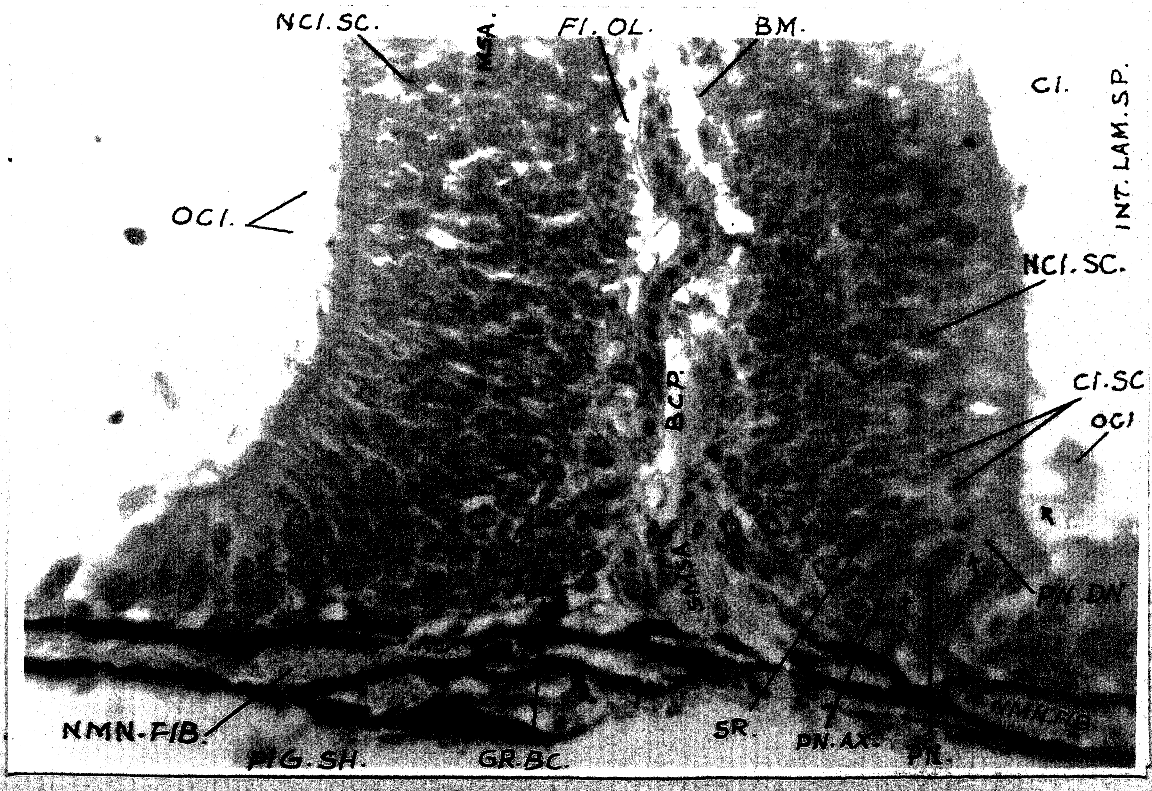


PLATE - 70

In the distal and proximal regions of the lamellae (LAM) the primary neurons(PN) are richly concentrated where as their rare occurrence can be noticed anywhere in the olfactory epithelium. The primary neurons can be easily identified by a round darkly staining nucleus and a fine cylindrical dendrite(DN) which extends to the peripheral surface(PL, 68,69,70,71,72,74) The axonal end(AX) of these cells are hardly traceable, as they are short, but at some points a clear axon(AX) can be seen which joins collectively to form folium olfactorium(FI.OL, PL70,71). The primary neurons are the independent cellular organization and never forms synaptic contact with other receptor.

In the thicker region of the olfactory epithelium the spindle shaped receptor cells(SR) occurrance is seen. These cells possesses elongated nuclear body and are found uniformly present in the deeper region of the olfactory epithelium. From where they sends their dendrites(DN) to the peripheral or distal region where they ultimately projects out in inter lamellar space(PL 71,74,75,76)

The short axon(AX) of the spindle receptor cells (SR)after coming out from the cell body, immediately joins

folium olfactorium(FI.OL, PL 68,71,75). These dendrites do not form synaptic contact with the axon of primary receptors(PN), hence both the receptors maintain their independent identity. The spindle shaped receptor cells(SR) are richly and uniformly supplied in the olfactory epithelium.

The goblet cells:

The goblet cells(GC) are richly distributed in the olfactory epithelium of Macrognathus aculeatus The rich occurrence of goblet cells(GC) can be noticed in the distal end of the lamellae(LAM, PL73,75,76). These cells of wine cup in structure having swollen ovoid theca with nuclear and cytoplasmic content pushed proximally in the form of a triangular mass. Due to the high degree of compression, the chromatin material and nucleolus are not visible(PL 71,72,73,75,76). The goblet cells(GC) of the olfactory epithelium are characterized by a beak, which projects into the interlamellar space(INT.LAM.SP). In Macrognathus aculeatus the goblet cells(GC) are found formed due to the transformation of primary supporting cells(SC) or basal cells(BC), hence there formative stages can be seen in the basal(BCZ) or primary supporting zones(SCZ). The migratory tendency is observed which brought them to the

Plate 71 Vertical section of lamella of M.aculeatus passing through middle terminal zone of pointed lamella showing mucosal and submucosal composition. Basal zone and supporting zone are also clearly visible.

Plate 72 Transverse section of lamella showing lumen with respect to lamellar arrangement and dense goblet supply as histoecological activity in lamellar surface. Magnification x 400.

AX.SR	Axon of spindle shaped receptor cell
BC	Basal cell
BM	Basement membrane
BCZ	Basal cell zone
CON.TIS.FIB	Connective tissue fibers
DN.SR	Dendrite of spindle receptor cells
FI.OL	Folium olfactorium
GC	Goblet cell
GC.TH	Goblet cell theca
INT.LAM.SP	Inter lamellar space
LUM	Lumen
NCI.SL	Non ciliated supporting cell
NU.GC	Nucleus of goblet cell
NMN.FIB	Non medullated nerve fiber
OCI	Olfactory cilia
PN	Primary neuron
PIG.SH	Pigment sheath
SR	Spindle shape receptor cell
SCZ	Supporting cell zone.

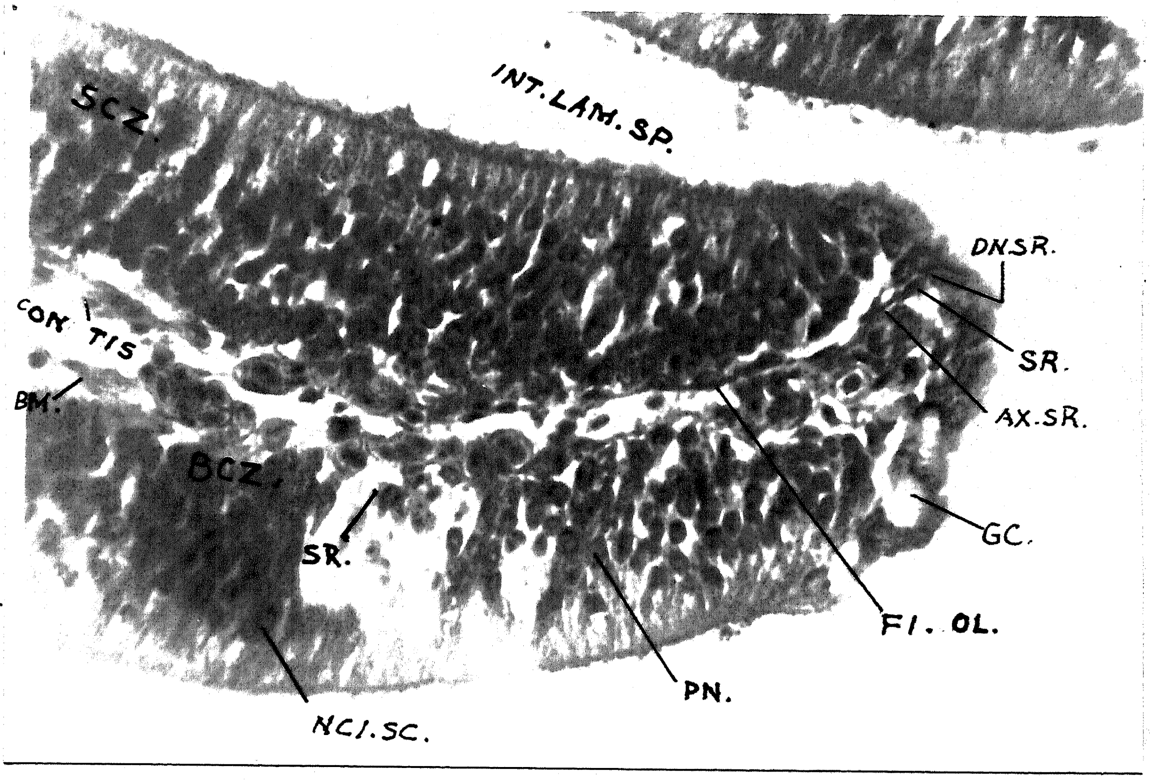


PLATE - 71

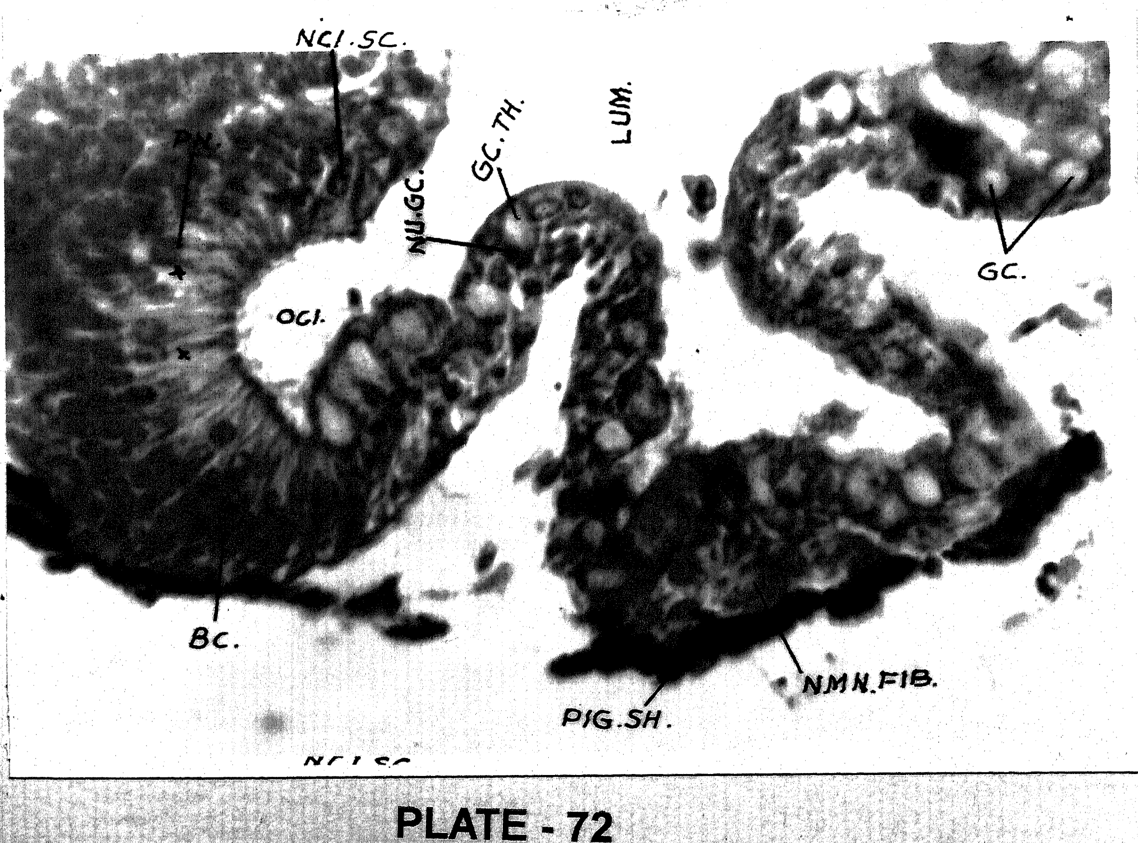


PLATE - 72

Plate-73 High power magnification of lamella of M. aculeatus
Showing clear architecture of goblet cell, supporting cells, receptor and other mucosal and submucosal composition. Arrow indicating dendritic and axonal extension. Magnification x 1000.

Plate 74 High power magnification of lamella of M. aculeatus showing morphogenetic activity in mucosa leading to demonstrate histo ecological peculiarity. Magnification x 1000.

AX	Axon
BC	Basal cell
CON.TIS.FIB	Connective tissue fibers
FI.OL	Folium olfactorium
FIB	Fibroblast cell
GC.	Goblet cell
GC.TH	Goblet cell theca
LUM	Lumen
MSA	Mucosa
MORP	Morphogenetic activity
NU.GC	Nucleus of goblet cell
NCI.SC	Nonciliated supporting cell
PIG.SH	Pigment sheath
PN	Primary neuron
SR	Spindle shape receptor
SMSA	Submucosa
SC	Supporting cell

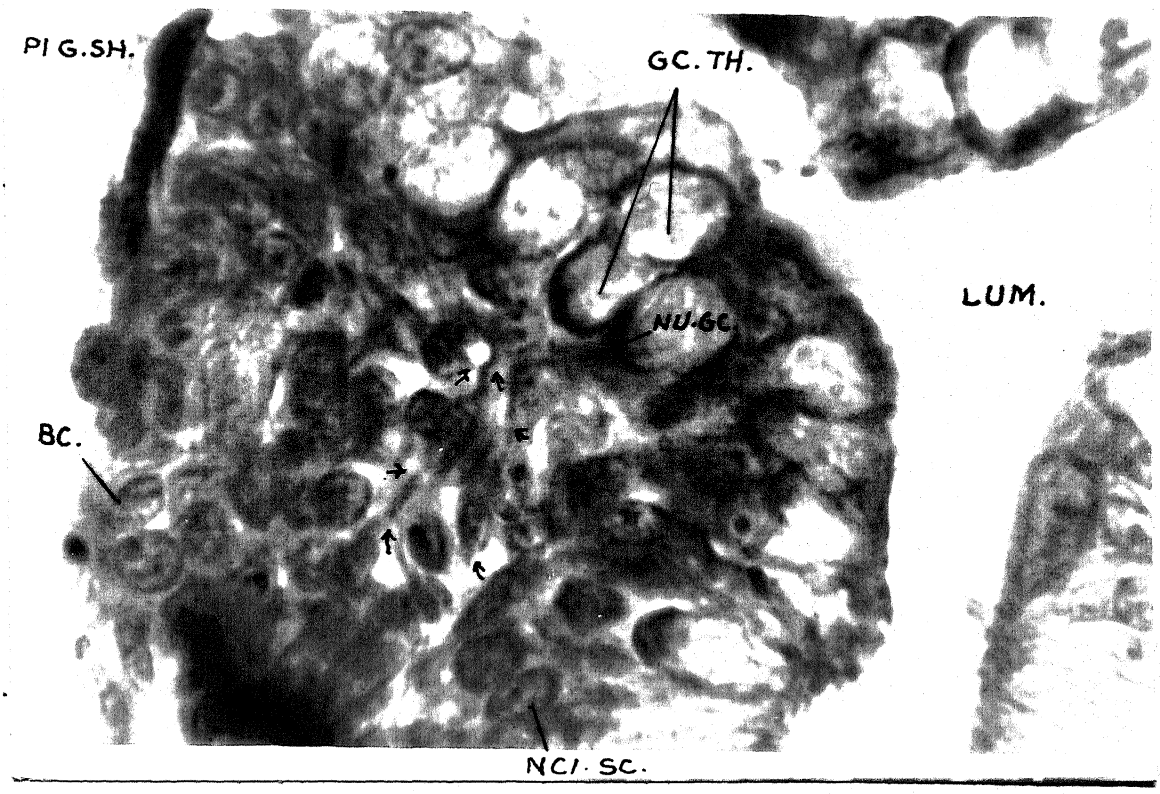


PLATE - 73

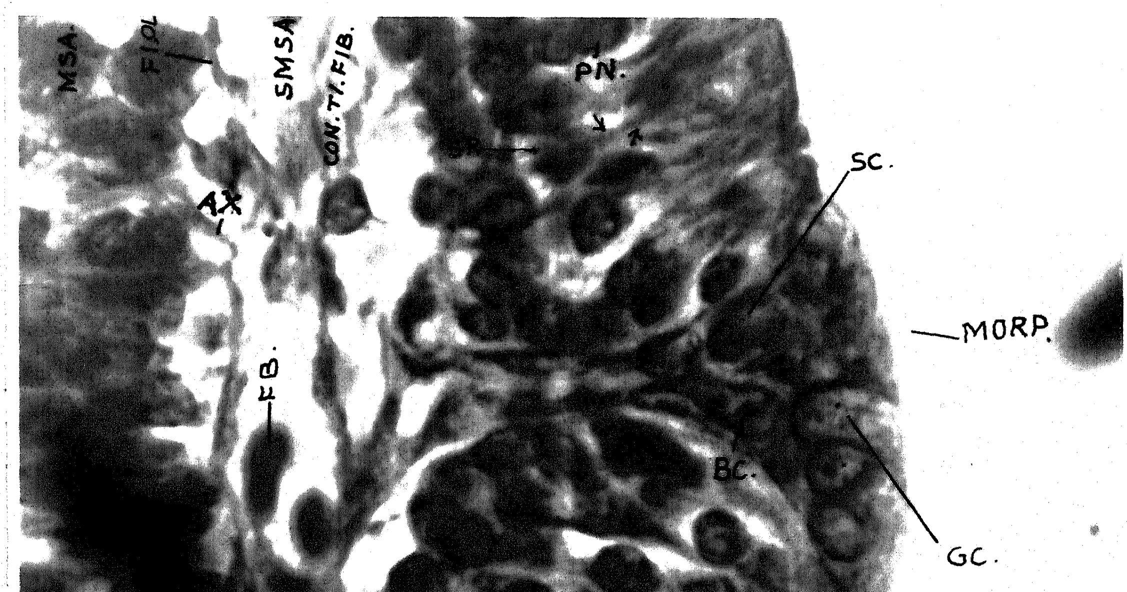


PLATE - 74

peripheral surface where mucous is discharged into the interlamellar spaces.

The basal cells:

The basal zone(BCZ) lies just above the basement membrane(BM) which is composed of basal cells(BC) arranged in three to four layers. These cells are aggregated (GR.BC, PL70) in the proximal intervening regions adjacent to the floor of the lamellae.

The basal cells(BC) are the smallest cellular component of the olfactory epithelium, having a round or oval shaped body with darkly staining nuclei and clearly visible nucleolus and chromatin material(PL 73,74,75). These cells are the mother cells of all the other cellular component of the olfactory epithelium. Some of the basal cells(BC) are muciperous and give rise to mucous secretory goblet cells at the distal region of the lamellae(PL 74,76). The basal cells(BC) also transforms in the primary supporting cells (NCI.SC) which ultimately get transformed into secondary supporting cells(CI.SC).

The central core or submucosa:

The central core or submucosa(SMSA) of the lamellae is separated from the mucosa by the basement membrane(BM, PL 68,69,71). The central core(SMSA) is found filled with dense connective tissues of collagen and reticular fibres. The connective tissues of this region of the lamellae is in continuation with the connective tissues lying in the periphery of the rosette. The matrix is found dense compactly cementing the connective tissue fibers (CON. TIS.FIB, PL 74) . The pigment cells(PIG) are confined in the connective tissues all around the periphery of the rosette but not in the submucosa(SMSA) of the lamellae(LAM, PL65). The central core or submucosa(SMSA) of all the lamellae is supplied with blood vessels of orbitonasal artery and vein.(PL 69,70,71,74)

The accessory nasal sacs:

The anterior accessory nasal sacs (ANT. ACC .NAS. SAC) in <u>Macrognathus</u> <u>aculeatus</u> is made up of cuboidal epithelium and are richly supplied with round goblet cells. In the internal lining of the sac hillock elevation(EL) and depressions(DEP) are seen which becomes more

Plate-75 High power magnification showing architectural pattern of receptor cells along with other cellular composition as the lamellar tip of M. aculeatus the passage of axon and dendrite to their respective zone.

Plate 76 Vertical section of floor of olfactory epithelium showing basal cell movement, goblet cell, ciliation and other peculiarities in olfactory epithelium of M. aculeatus. Magnification x 1000.

AX.SR	Axon of spindle shape receptor cells
BCZ	Basal cell zone
BC	Basement membrane
CI.SC	Ciliated supporting cell
CI	Cilia
FIB	Fibroblast cell
FI.OL	Folium olfactorium
GR.PN	Grouping of primary neuron.
GC.TH	Goblet cell theca
GC	Goblet cell
MSA	Mucosa
MI.BC	Migratory basal cell
NCI.SC	Nonciliated supporting cell
NU.GC	Nucleus of goblet cell
OCI	Olfactory cilia
PN	Primary neuron
SCZ	Supporting cell zone
SR	Spindle shape receptor

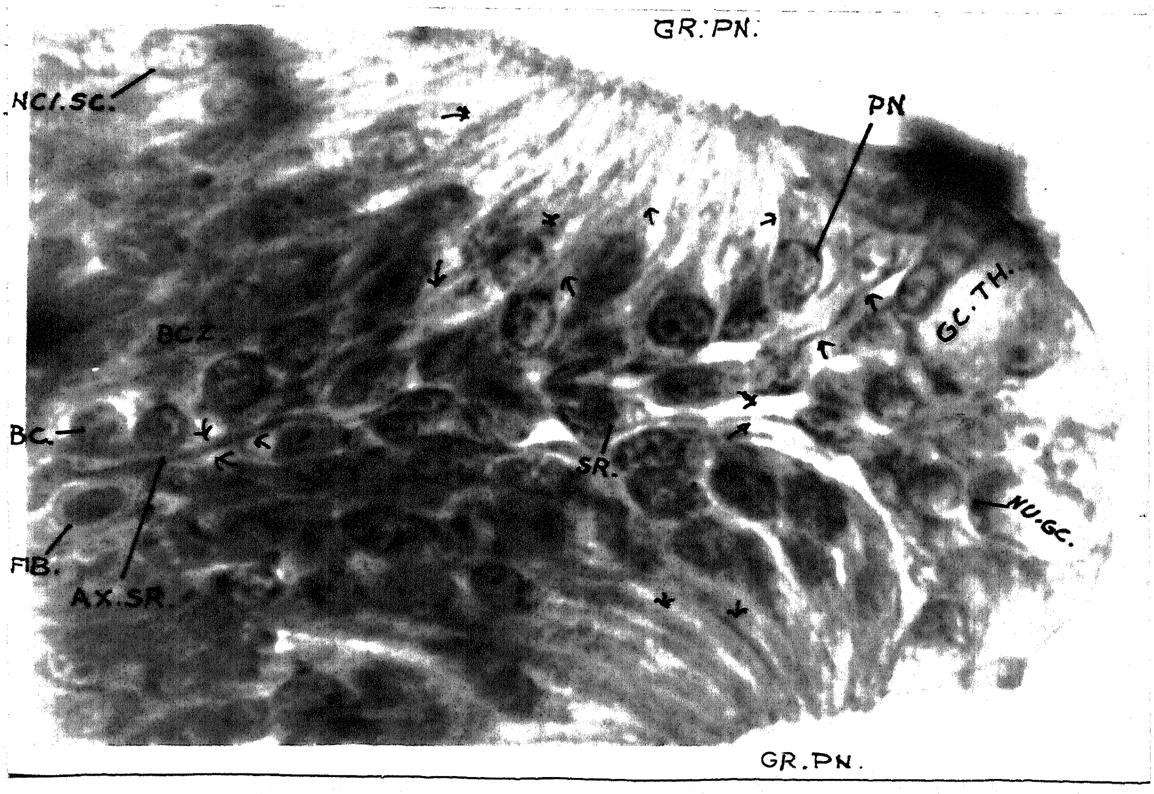


PLATE - 75

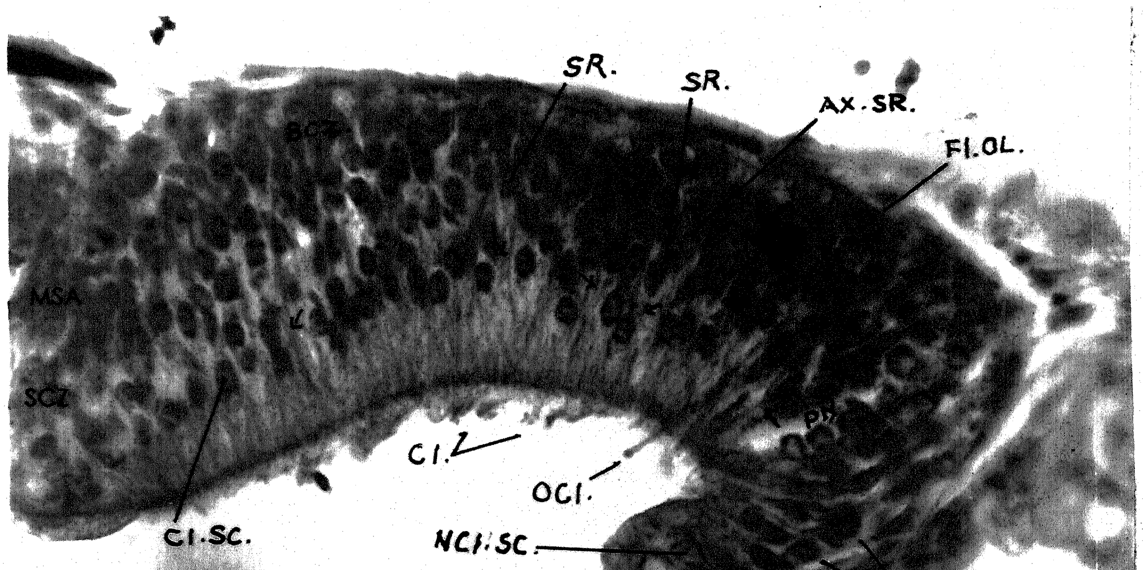


PLATE - 76

prominent in the posterior side. The peripheral lining of the sac is a constitution of cuboidal supporting cells(CU.SC) with intervening mucous secretory goblet cells(GC), while the inner or proximal region is filled with basal cells(BC) and connective tissue fibres(CON.TIS.FIB, PL76). The anterior nasal tube is lined with nonciliated cuboidal supporting cells and is provided with cell processes. The mud and the other foreign particular are found intermingled in the mucus, from the water passing through the nasal sac and mud free water is allowed to the lumen of the rosette. The mud and other foreign particles deposited in the sac is removed by reserve water current which is created by the compression of infranasal chamber(INF.NAS.CH, PL 62) and closing of posterior nasal opening(POST.NAS.OP). Thus the accessory sac is an additional device to this mud dwelling fish for creating reverse water current, thus cleaning the olfactory chamber .

Unidirectional flow of water

The constant valvular movement of the surface of the posterior nasal opening(POST.NAS.OP) synchronously with the opercular movement creates an antero posterior suction

pressure which invites water current from the anterior nasal opening(ANT.NAS.OP). The water current is brought to the lumen(LUM) of the rosette(RE) via the tubular passage of the anterior nasal tube(ANT.NAS.TUBE) and anterior accessory nasal sac(ANT.ACC.NAS.SAC) , from where it flows antero posteriorly due to the unidirectional movement of cilia(CI), over the olfactory rosette and goes out by the postero ventral aperture which lies underneath the posterior nasal opening(POST.NAS.OP) and coinciding to the aperture of infranasal chamber(INF.NAS.CH). The water current circulates through the infranasal chamber(INF.NAS.CH) before its final expulsion from the posterior nasal opening(POST.NAS.OP). The mud and other foreign materials are entangled in the accessory sac by the mucous secretion and mud free water is allowed in the lumen of tubular rosette. The accessory sac is cleaned by the reverse water current created by the compression of infra nasal chamber and closing of the posterior nasal opening. It is an additional device for this mud dwelling fish, where the reverse water current repeatedly cleans olfactory passage. In this way the circulation of water takes longer route of transportation through the olfactory chamber of <u>Macrognathus</u> <u>aculeatus</u>

Plate-77 Vertical section passing through anterior accessory nasal sac. Showing sac space and other cellular composition. Magnification x 400.

Plate-78 Vertical section passing through infra nasal sac. Showing its cellular composition and pigment sheath alongwith sac. Space Magnification x 400

BC	Basal cell
CON.TIS.FIB	Connective tissue fiber
CU.SC	Cuboidal supporting cell
GC	Goblet cell
GC.TH	Goblet cell theca
NU.GC	Nucleus of goblet cell
PIG.SH	Pigment sheath
SAC.SP	Sac space.

Histoecological Variations:

The Macrognathus aculeatus possesses a long barrel shape rosette(RE), having compact cellular organization(PL 62,63), but it is seen that to cope up with changed environmental condition sometimes its submucosa(SMSA) exhibits morphogenetic activity(MORP) resulting the flow of cellular contents towards periphery. This activity increases the surface area due to the migration of basal cells(BC, PL 68,74) at the peripheral surface. Beside this in Macrognathus aculeatus three types of lamellae are noticed the lamellae with pointed tip at anterior end with expanded tip in middle and with pointed or expanded tip at posterior end increasing the efficiency of the fish(PL 64,66,67). In Macrognathus aculeatus at the lamellar tips, the goblet cells are richly distributed(PL 73,75,76) which act as an potent device in this mud dwelling fish, for making water mud free, by entangling foreign particles in the mucus secreted and collected from a olfactory sensory surface. This foreign mass is forcefully pumped out by strong water current going out through posterior nasal pore. The mucus secretion form a slimy layer all around the olfactory mucosa protecting it

form forceful circulation of water current and stricking foreign bodies passing with water .

Ecological coefficient of Macrognathus aculeatus:

Usually two methods are employed for calculating the ecological coefficient of olfactory and optic faculties of Macrognathus aculeatus for making approximate assessment of the capacity of these two faculties from the anatomical point of view.

Five fishes of different sizes ranging from 153mm to 250mm are selected for calculating the ecological coefficient. The number of lamellae and length of fish increases successively with the age of the fish (Table 2) . The length of the mesencephalon ranges from 2.13 mm to 3.14mm and that of telencephalon from 2.72mm to 3.48 mm. The ecological coefficient is calculated ranging from 106.06 to 127.69 which indicates that the olfactory center is more developed than that of optic.

The area of two retina ranges from 10.86 mm^2 to 20.22 mm^2 and that of two rosettes from 27626 mm^2 to two retina stands insignificant as compared to the faculty. The ecological coefficient ranges from 2543.83 to 2805.78 percent. Thus olfactory center in the brain also exhibits

marked domination over the optic center. It is now clear that the fish under study is a "nose fish" and sense of olfaction plays an important role in the habit of the fish. The fish lives in mud tubes or in dark places where olfactory faculty is utilized for locating the food material and fright reactions etc.

Table 3 Ecological coefficient of Macrognathus aculeatus

S.No	Stand length mm	No. of Lamellae Right Left	Total length of Brain mm	Length of Mesencepholon mm	Length of Telen Cephalon mm	Ecological cofficient $\frac{\text{length of telecepholon} \times 100}{\text{Lingth of mesen cephalon}}$	Retinal Area of Both Eyes mm^2	Olfactory Area of both Rosette mm^2	Ecological Cofficent= $\frac{\text{Olfactory area x100}}{\text{Retinal Area}}$
1	153	80 80	1021	2.13	2.72	127.69	10.86	276.26	2543.83
2	168	86 86	12.00	2.56	3.05	119.14	11.06	310.32	2805.78
3	223	98 98	14.00	2.97	3.15	106.06	15.48	394.70	2549.74
4	230	98 98	14.58	3.00	3.20	106.66	15.48	415.74	2685.65
5	250	110 110	15.25	3.14	3.48	110.82	20.22	554.00	2739.86
						114.07			2664.97

Discussion

DISCUSSION

Nasal opening:

The olfactory chamber in the fishes communicated to water by a pair of nasal openings which are used for transportation of water through the olfactory chamber and not for breathing unlike higher vertebrates. In teleosts a pair of nasal opening is present in each olfactory chamber and are named as inlet anterior and outlet posterior nasal opening. The two nostrils are so adjusted that one serves to intake the water an other for its exist(Allison,1953; Lagler et al, 1962; Malyukina et al, 1969 and Hara ,1975). According to Basteson (1889), Burne (1909), Teichmann (1967), Hara (1975), Sharma (1981), Yadav(1989) and Dubey (1991) the olfactory chamber of most of the bony fishes bears two nasal openings which shows considerable variations in their shape, size and location in different fishes. In some fishes anterior nasal opening is widely separated from the posterior, while in some they lies very close to each other Lagler (1962) , Norman (1963) , Gupta and Srivastava (1973) has described single nasal opening in the olfactory chamber of some fishes. According to Burne (1909) the

presence of single nasal opening may be the condition created by the elevation of the floor an subsequent rupture of the bridge between the nostrils.

In the present study of Rita rita, Macrognathus aculeatus and Anabas testudineus the olfactory chamber of all three fishes bears incurrent anterior and excurrent posterior nasal openings. In Rita rita anterior nasal opening is spherical while in Macrognathus aculeatus and Anabas testudineus tubular nasal opening is present. Basteson (1889) and Kapoor and Ojha (1973b) advocated that the presences of anterior tubular nasal opening is a characteristic of a fishes with predominantly developed olfactory faculty. Kapoor and Ojha (1972a and 1973b) reported that when anterior and posterior nasal opening are separated from each other by some distance , the former is invariably born on a tube . The presences of well defined tubular anterior nasal pore is in a accordance with the idea of Bateson (1889) , Burne (1909) , Kapoor and Ojha (1972a and 1973b) because both these fishes has a well developed olfactory faculty. In Rita rita and Macrognathus aculeatus the distance between the two nasal openings is moderate and both are found situated at two extremes of the head, while in Anabas

testudineus the nasal pores are closely situated. In Macrognathus aculeatus anterior nasal opening is typically lies extremely projected on both the sides of fleshy rostral appandage , keeping it protruded out through mud holes during its normal dwelling posture.

The posterior nasal opening are also of various shapes, they may be circular , oval, bean shaped, cresentric or rectiangular. Burne (1909) reported that the size and shape of the posterior nasal opening vary significantly in different species. In Anabas testudineus posterior nasal opening is circular in shape, while in Macrognathus aculeatus and Rita rita it is oval shaped aperture.In Macrognathus aculeatus the posterior nasal opening is surrounded by loose area of integument which performs valvular movement by continuously throwing the surface in and out. The present author is of the opinion that in most of the fishes anterior nasal opening is situated above the surface in different forms , but posterior is generally flush with surface of the skin. This placement of the anterior nasal opening above the surface of the head helps in the entry of water current during forward progression of the fish. Similarly the

posterior nasal opening flushed with body surface of fish, allows the exit of same current without any hindrance.

The olfactory rosette:

The organ of olfaction are represented by a pair of olfactory sacs, which in sharks and rays are located on the central surface, while in sturgeon and bony fishes on the dorsal surface of the head . The nasal sacs are lined by the olfactory epithelium, which is generally raised from the surface of the organ into complicated series or fold called lamellae to make a rosette (Hara 1975) .The shape of the olfactory rosette varies greatly in different species. Bateson (1889) distinguished four types of rosette on the basis of their shapes Burne (1909) reported three types of rosette ; oval (in most fishes) ; round (Esox) and elongated (Anguilla) . The fishes with oval rosette are most common but with elongated rosette show dominantly developed olfactory faculty . This finding can be justified with present study as elongated rosette in <u>Rita rita</u> and <u>Macrognathus aculeatus</u> displayed predominant olfactory behavior.

In the present investigation it is found that, the olfactory rosette are subjected to a great modification with the shape and size of the olfactory chamber. The position of olfactory chamber is found close to the eyes in Anabas testudineus, while in Rita rita it is moderately elongated and is situated close to the snout away from the eyes . In the case of Macrognathus aculeatus it is typically elongated covering whole of the snout and opening out extreme terminally on both sides of fleshy rostrum . Hara (1975) in Eels and Morray , Ojha and Kapoor (1972a) in Wallago attu and Sharma (1981) in Heteropneustus fossilis reported the presence of olfactory chamber close to the snout. Rosette is found bean shaped in Rita rita , barrel shaped in Macrognathus aculeatus and quadrangular shaped in Anabas testudineus. In Macrognathus aculeatus elongation of jaws causes the formation of tubular ethmodial region which is completed filled with barrel shaped olfactory rosette.

In the present study except Rita rita remaining two fishes that are Macrognathus aculeatus and Anabas testudineus are rapheless . The absences of raphe in olfactory rosette is in accordance to Singh (1972) , Bertmar (1972) , Kapoor and Ojha (1973 a , and 1979) and Rahmani and Khan

(1977) who concluded that raphless fishes has comparatively lesser number of lamellae and the author disagree with this view as in Anabas testudineus lesser number of lamellae are found , but contrary to this in Macrognathus aculeatus the number of lamellae is numerous though it is rapheless.

The number of lamellae are greater in Rita rita and Macrognathus aculeatus but in Anabas testudineus only seven to ten lamellae are only present. The author observed that the lamellae shows a clear cut increase in their number with total length of all the fishes under investigation and this finding is in agreement of Basteson (1899) , Burne (1909) , Teichmann(1954) . Johnson and Brown (1962) , Kleerekoper (1969), Ojha and Kapoor (1971,1972,1973 a,b and 1974) , Hara (1975) and Sharma (1981). However Rahmani and Khan (1977) found that in adult fish the number of lamellae varies from seven to ten and no correlation can be established between the number of lamellae and size of the fish.

Histology of the accessory nasal sacs

The structure of accessory nasal sac is studied by Kyle (1899), Burne (1909), Pipping (1926), Liermann (1933),

Teichmann (1954) , Eaton (1956), Johnson and Brown (1962), Kleerekapor (1969) , Gooding (1963), Kapoor and Ojha (1972), Ojha and Kapoor (1973), Zeiske (1974) , Rahmani and Khan (1977) and Sharma (1981) . The cellular structure of accessory nasal sac is however described in detail by Bertmar (1969) , Rahmani and Khan (1980) , Sharma (1981) and Yadav(1989).

In the present study, the detailed histological aspect of accessory nasal sac is decribed in all the three fishes under present investigation. In Rita rita the sac is named as ventro lateral accessory nasal sac as it is situated ventrolaterally to the olfactory chamber in association with olfactory rosette. In Anabas testudineus a well developed ethmoidal and lacrymal accessory nasal sacs are reported as they are present in relation to these bones. In case of Macrognathus aculeatus the anterior accessory nasal sac is found present typically extreme anteriorly to the olfactory rosette extending directly to anterior nasal tube, while infra nasal chamber is communicated to posterior nasal opening and lying parallel to the posterior extremity of rosette below lacrymal bone. In Macrognathus aculeatus sacs are lined by the cuboidal

epithelium where mucus secretory goblet cells are aggregated in form of hillock elevations or tree like projection.

In Anabas testudineus the ethmoidal sacs are large , situated slightly above the main olfactory chamber while lacrymal sacs are small , narrow and extend upto the greater length. In Rita rita the ventrolateral accessory nasal sac is composed of cuboidal supporting cells, basal cells and goblet cells . The excessive mucus secretion through these sacs in present fishes lubricates total olfactory passage protecting it from mechanical harms and entangling unwanted foreign bodies into it which latter on flushed out with outgoing water current. Mucus secretion also help in olfactory reception by holding reactionary content near the receptory surface.

The accessory nasal sac in all the three fishes under investigation are constituted of outer mucosa and inner submucosa. It is perfectly non sensitive secretory structure encircling a lumen for the accumulation of water. The mucosa is found composed of cuboidal supporting cells, basal cells and of beaked or simple mucus secretory goblet cells . Receptors are totally wanting in the accessory nasal of all the three fishes. The submucosa is made up of connective

tissues fibres, fibroblasts, histocytes, lymphocytes, basal cells, blastema cells and pigment cells. Rahmani and Khan (1981) , Sharma (1981) , Dubey in (1991) reported accessory nasal sacs revealing same histological concept as reported in the present study of Rita rita, Anabas testudineus and Macrognathus aculeatus. The elastic connective tissue fibres have also been observed in the histological section of ethmoidal an lacrymal sac , presenting a specific concept as an instrument for forcibly circulating the water through olfactory epithelium

The finding highlighted by Rahmani and Khan (1981) and Sharma (1981) are restricted to the concept that they are additional accommodation for water in the olfactory chamber however the present findings has revealed that they are not only pumping structure for forcibly drawing the water through the olfactory surface for convenient and prompt reception of olfactory sensation and also to lubricate the whole olfactory passage protecting it from mechanical harms by forceful circulation of water current. The presence of different types of accessory nasal sac in association with olfactory chamber of Macrognathus aculeatus, Rita rita and Anabas testudineus provide histoecological supporting

device to the fishes under study and helped them to with stand completely in the prevailing environment with this enhanced structural architecture. The fishes under study are having diverse habit and habitat and olfactory epithelium is subjected to constant touch with environmental fluctuations which are matched with the presences of accessory nasal sac alongwith their pumping and excessive mucus secretory character.

The circulation of water:

In all the fishes under investigation, namely Rita rita , Anabas testudineus and M. aculeatus, it is observed that the water enter into the olfactory chamber through anterior nasal opening, and leaves it via posterior nasal opening. In other words, it can be said that unidirectional flow of water exist in these fishes.

The author thinks , that irrespective of architectural difference of the two nasal opening, the water always flow from anterior to posterior direction in the olfactory chamber. Doving et al (1977) reported that the direction of ciliary beat is consistent with the direction of water current, meaning

that the cilia beats from anterior to posterior side of the olfactory chamber. Beside this Eaton (1956) , Johnson and Brown (1962) and Kapoor and Ojha (1973a) found out that the water enters in the chamber through both the openings and is expelled out through the posterior opening (Johnson and Brown , 1962) or through both openings (Kapoor and Ojha 1973a) .

But the present author is in accordance to Dvoving et al (1977) , because the beating of cilia helps in creating the water current from anterior to posterior direction as the entry of water through the posterior opening will be an hindrance for the movement of cilia and will effect uniform flow of water. Thus unidirectional flow water from anterior to posterior direction required for efficient working of cilia.

All the three fishes selected in present study possess cilia in their olfactory epithelium which help the water to circulate in the antero- posterior direction of the olfactory rosette.

Besides antero posterior beating of cilia of the olfactory epithelium, the location of anterior nasal pore also helps in

establishing incurrent of water. The architectural pattern indicates that in forward movement of fish water will compulsory enters through anterior and exists through posterior nasal opening after irrigating the olfactory epithelium.

The water current also enters the olfactory rosette due to the contraction and expansion of accessory nasal sacs. In the present study the accessory nasal sacs are present in all three fishes. In Anabas testudineus the well developed ethmoidal and lacrymal sacs are present . The ethmoidal sac are long , mediodorsal sac lying slightly above the main olfactory chamber, but lacrymal are small narrow and extends to the length of maxillaries . In Rita rita ventro lateral and in Macrognathus aculeatus anterior accessory sacs and infra nasal chamber are found respectively, with regards to their position. In Rita rita this sac is an extension of the olfactory epithelium to the ventro lateral side of the chamber, while in Macrognathus aculeatus it is fromed due to the modification of anterior tubular nasal opening. The accessory sacs of all three fishes are found richly supplied with mucus secretory goblet cells, which allows mud free water to the olfactory rosette by entangling dust and foreign

particles. The clearance of olfactory passage take place due to the creation of reverse water current.

According to Doving et at (1977) when the movement of water across the olfactory chamber is brought about by the ciliary action, the fishes are called as isomates and when it involves the compression and expansion of the accessory sacs, the fishes belong to cyclomates categories . In present investigation Rita rita and Anabas testudineus are cyclomates, while Macrognathus aculeatus cannot be placed under this category, though accessory sac is present because the water current is created through the olfactory chamber, due to the continuous valular movement of posterior nasal opening . Doving and Thommeson (1977) has divided the olfactory passage in to vestibule, corridors and gallery. In Macrognathus aculeatus vestibule takes the shape of lumen which opens anteriorly into anterior nasal sac and posteriorly into the infra nasal chamber.

In Anabas testudineus the circulation of water has short route , while Rita rita and Macrognathus aculeatus has longest route .

Discussion of histology

The investigation carried out by all previous workers has revealed that the olfactory epithelium is composed of olfactory receptors cells, intermingled with supporting cells (Hopkins,1926, Kolmer, 1927; Allison, 1953 ; Bloom 1954 ; Le Gros Clark , 1957; De Lorenzo, 1957; Ottoson, 1963; Porter and Bonneville, 1964; Frisch, 1967; Moulton and Beidler, 1967) , basal cells and mucus secretary goblet cells. The fine structure of olfactory epithelium has been studied in number of fishes by Trujillo- Cenoz(1961),Bannister (1965) , Bronshtein and Ivanov (1965) , Vinnikov (1966) , Wilson and Westerman (1967) , Thornhill (1967) , Gemne and Doving (1969), Kleerekoper (1969) , Schulte and Holl (1971), Bertmar (1972), Ojha and Kapoor (1973), Kapoor and Ojha (1974) , Hara (1975), Yamamoto and Ueda (1977,1978 a-f) , Zeiske et at (1979) , Theisen et at (1980 Rahamani and Khan (1980) Sharma (1981), Singh and Singh (1986), Doroshenko and Motavkin (1987) , Yadav (1988), Dubey (1991) and Singh et at (1996). It is traced out that basic plan of olfactory epithelium of fish shows no fundamental variations from the general vertebrate pattern. The olfactory epithelium of each lamellae consist of two

principal layers, the outer mucosa supplied with supporting, secretory, sensory and other cellular elements, while the inner submucosa or central core is supplied with connective tissue fibers, blood supply, nervous elements, basal cells, blastema cells, fibroblast, histocytes and other cell system required for the discharge of nutritional and protective functions against infection and injuries. The relative thickness of mucosa and submucosa varies greatly from fish to fish and some times even in the lamellae of the rosette. The basement membrane stands as partition in between submucosa and mucosa and act as a medium for the exchange of nutritional and nervous supply. The similar cellular organization of the olfactory epithelium with individual variations in the arrangement and shape of a particular cell type has been observed in the study of Rita rita, Anabas testudineus and Macrognathus aculeatus.

In the present comparative study of olfactory epithelium of the olfactory organ of all three fishes are subjected for exploratory study and it is observed that olfactory epithelium of Rita rita exhibit morphogenetic activity which results in the formation of bulging, hillock elevation, depression, ciliary clustering, narrowing, swelling

curving, budding and cell balls of various shape and size. The activity of mucus secretory goblet cells is also pronounced in the olfactory epithelium of Rita rita. These morophogenetic activity is the resultant of the migration of basal cells through the cellular spaces created by the fussion or death of goblet cells after discharging their mucus contents. In Anabas testudineus the morphogenetic activity solely depends on the bulk of basal cells and their subsequent flow in any direction creating microformation in the form of secondary lamellae which can be in cuneiform, filiform and fungiform shapes. Besides this grooving, hillock elevation. The depressions of varied shape and sizes has been observed on the lamellar surface of Anabas testudineus. Thus in this fish moderate morphogenetic activity is seen, which resembles C.nama and C.fasciatus(Dubey 1991) , while the activity in Rita rita can be compaired to C.carpio and H.fossilis (Sharma 1981).

The morphogenetic activity of basal cells in submucosa along with discharge of mucus by goblet cell in Rita rita leads to creat crupts of variable shape, size and at different depths. The crupts may be present on the margin of Rita rita opening in inter lamellar space in different manners, but specifically it is observed that some crupts are unexposed and

situated as deep vacuole in different part of mucosa. The morphogenetic activity in mucosa may also lead to bifurcations which may give rise to minor lamellae in the basal, middle and terminal region of lamella. Such lamellar are fully composed of mucosa having off shoots of submucosa .

In Anabas testudineus the morphogenetic activity of basal cell is physiological dependent on the bulk of cells present in mucosa, submucosa and their subsequent migration to peripheral surfaces leading in the creation of secondary lamellae on mucosal surface in some specified middle lamellae. The minor lamella in between two lamellae are also observed in Anabas testudineus which is also a result of multiplication of basal cell consequently giving rise to minor lamellae.

The author is of the opinion that specific formation on the lamellar surface of the above mentioned fishes in the form of bulging, regular elevations and depressions, flattering, hillock elevation, ciliary clustering, narrowing swelling, curving, budding cell ball and secondary lamellae are the reality of morphogenetic activity and are in direction

of increasing the sensitive area of the olfactory surface to cope up with the environmental changes.

In the case of Macrognathus aculeatus lamellae has well demarcated zone of sensory and non sensory area. The distal tip of each lamella is though devoid of sensory cells but is richly secretory. Zonation in the lamellae of Macrognathus aculeatus is in accordance with the finding of Sharma (1981) in Mastacembalus armatus armatus and Dubey (1991) in Colisa fasciatus. The author thinks that such zonation and presences of goblet cells at the tips are due to the condition in which the fish lives, as it minimizes the friction between the body and the water, and allows smooth flow of water in the olfactory chamber. The presences of tree like projection of epithelium in the nasal tube of this fish play important role in the life of this fish as it is a mud dwelling fish and this feature is in accordance with Sharma (1981) in Mastacembalus armatus .Beside this, at some places the flow of basal cells at the periphery is seen and meant for increasing surface area to with stand in diverse conditions. The specific formations on the lamellar surface are reported by Bertmar (1972), Rahmani and Khan (1980) , Sharma (1981) , Yadav (1989) and Dubey (1991). The tremendous

morphogenetic activity on the lamellar surface is reported in Heteropneustes fossilis , Cyprinus carpio (Sharma 1981) , Nandus nandus (Yadav 1989) , Clarias batrachus and Chanda nama (Dubey 1991) . In Rita rita cellular distribution become so distinctive that the lamellae are divided into initial, middle and hinder lamellae. The initial and middle lamellae are notice morphogenetically active, while hinder ones are worn out. Beside this, the distribution of sensory , supporting and goblet cells is in such a manner that the lamellae can be further divided into zones : proximal , middle and distal zone. These findings are in accordance of Rahmani and Khan (1980) , Sharma (1981) and Yadav (1989). In Macrognathus aculeatus the two types of lamellar tip are identified ; the anterior broader and posterior keel shaped or pointed as founded in Mastacembalus armatus(Sharma 1981). In diverse ecological conditions, it is noticed that latter fish send its submucosal off shoot to the periphery and the rapid multiplication of basal cells in that portion increases the lamellar surface. Thus the author concludes that all the morphgenetic activity on the lamellar surface and distinct distribution of cellular contents it to with stand in the diverse ecological conditions which are developed in particular habitat.The author also shares the view of Gautam

and Gautam (2000, 2001 and 2002) who reported directed effect of pesticides biologically, hematologically, histopathologically and biochemically on gastro intestinal mucosa and submucosa . In accordance to above authors the olfactory mucosa of all the three fishes under study is seen effected with some unknown reactant present in circulatory water current. Damage in connective tissue is also seen apparently in Rita rita . No water in present circumstances is free from detergent pollutants, therefore damage caused in mucosa and submucosa can be commonly visualized in cellular architecture , in all the three live fishes.

The supporting cells:

The supporting cells are main cellular constituents of all the visceral organs of the vertebrates and plays important role in sensory organs. Hopkins (1926) , Kolmer (1927) , Allison (1953), Branson (1963), Watling and Hillemann (1964), Bannister (1965) has described the presences of ciliated supporting cells in the olfactory epithelium. They were in the opinion that the olfactory epithelium of sacs are exclusively composed of ciliated supporting cells. Contrary to it Holl (1965) , Bertmar (1972) , Rahmani and Khan (1980) ,

Sharma (1981) Singh and Singh (1986) and Dubey (1991) has categorically described supporting cells in the form of ciliated and non ciliated supporting cells. According to Ojha and Kapoor (1973) the supporting cells bears 8 to 12 cilia implanted on the basal body of these cells in their extreme distal tip.

In the present study of olfactory mucosa of Rita rita Anabas testudineus and Macrognathus aculeatus the author has traced, the presence of ciliated, non ciliated and transitionary supporting cells arranged in well demarcated zones. In Rita rita the distal zone is non ciliated while proximal region and middle region are exclusively ciliated. In Anabas testudineus ciliated cells are present mostly in the slopes of the fungiform secondary lamellae and also at the inter lamellar junction , while non-ciliated supporting cells are more common and occupy the greater part of the olfactory epithelium . In Macrognathus aculeatus at the periphery all the supporting cells are ciliated, while nonciliated supporing cells are present in second row an act as a transtionary cells. Bertmar (1972a) reported that there is no difference between the two types of supporting cells in their abundance or relation to the receptors , but when the

supporting cells lies together, the group consist one type of cell. In accordance with Bertmar(1972a), finding of Yadav (1989) and Dubey the grouping of ciliated and non ciliated supporting cells riches up to such extent in Rita rita that the ciliated and non ciliated zones are clearly visible .

In Rita rita the ciliated supporting cells are confined to the proximal region of the lamellae on both the sides to the raphe demarcating supporting and sensory zone , while the distal zone is provided with nonciliated columnar cells intermingled with mucus secretory goblet cells. Thus their occurs a clear cut demarcation between negligible secretory ciliated and non ciliated highly secretory zone. The author shares the view of Rahmani and Khan (1980) , Sharma (1981) Yadav (1989) and Dinesh P.Singh (1992) that the grouping of different types of supporting cells in a zone or in small groups may be for some functional significance as reported in Rita rita .Anabas testudineus and Macrognathus aculeatus , the non ciliated supporting cells are subjected to a process of continuous transformation into the mucus secretroy goblet cells, therefore in latter fish whole of the distal surface of the lamellae is seen occupied by the theca of goblet cells Ojha and Kapoor (1973) in Labeo rohita, Kapoor

& Ojha (1974) in Channa punctatis and Sharma (1981) in C.carpio observed the transformation of supporting cells into the goblet cells. In accordance to the finding of these workers, the muciferous activity of supporting cells in the secretory zone of the lamellae in Macrognathus aculeatus has been observed, on mass level, while in Anabas testudineus they are traced at some places. According to Moulton and Beidler (1967) the supporting cells play their significant role in showing their secretary and nutritional activity rather than merely providing mechanical support to the receptor cells. On the other hand Gerebt Zoff and Shekapenko (1952) contradict the idea regarding the secretary nature of supporting cells. Histological observations reveals that the nonciliated supporting cells of Rita rita are supplied with muciferous cytoplasm which may convert in the secretory fluid converting supporting cells in goblet cell. In Macrognathus aculeatus secretory goblet cells can be seen in supporting and basal zone in different stages indicating their transformation form supporting and basal cells. Thus the author shares the view of Moulton and Bediler (1967). Le Gros Clark and Warwick (1946) , Bloom (1954) Yammoto et al (1965), Frisch(1967) , Seiffert (1969) observed secretory fluid or granules in the supporting cells of different animals.

The muciferous activity in the supporting cells has been reported by Ojha and Kapoor (1973) in Kapoor and Ojha (1974) Rahmani & Khan (1980), Sharma (1981), Yadav (1989) Dubey (1991) and D.P. Singh (1992). The present author has noticed muciperous activity in the supporting cells of Rita rita, Anabas testudineus and Macrognathus aculeatus and has concluded that goblet cells are generated from the supporting cells. The degree of occurrence of goblet cells depends upon the habit and habitat of fish, as they are support histological by sectory mucosa for lubricating whole of the olfactory passage and to provide mechanical strike absorbing device for circulating water current.

The distribution of supporting cells in Macrognathus aculeatus is uniform and no zonal distinction is seen in the fish with respect to their arrangement in the olfactory epithelium.The author traced out that in Anabas testudineus, the distribution of supporting cell is not uniform. The ciliated supporting cells are found more on slopes while non ciliated are common in depressions, which is also suggested by Rahamani & Khan (1980). In Anabas testudineus among ciliated supporting cells receptor cells are also found, thus the ciliation is of moderate type and no bunching or clustering of

cilia is reported in Anabas testudineus This is in accordance with the finding of olfactory epithelium of Esomus denricus (Sharma 1981) , Nandus nandus (Yadav 1989) and Chanda nama(Dubey 1991).

The ciliation of Rita rita and Macrognathus aculeatus is in agreement with the finding of olfactory epithelium of M.armatus armatus, H.fosslis (Sharma 1981) , Oxygaster bacaila (Yadav 1989) . In these fishes the supporting cells are uniformly ciliated , but at the periphery of the lamellae the ciliation becomes more prominent forming long tuff of cilia, which helps in creating water current. In Macrognathus aculeatus the supporting cells are closely packed. They are cuboidal in nature allowing the complete isolation to the dendrites of the receptor cells. The supporting cells of the olfactory epithelium of Macrognathus aculeatus are intermingled with the frequent distribution of the goblet cells. The supporting cells are arranged in such a manner that uniformity of the free distal surface of the lamellae in Macrognathus aculeatus is maintained . These are uniformly ciliated and proximally followed by the primary supporting cells, an advance stage of basal cells leading to the formation of ciliated supporting cells. In the extreme distal tip of the

lamellae, a marked absences of supporting cells is noticed and place is occupied by the primary neurons which remains in direct contact with the water circulation through the central passage or lumen of the rosette as in Mastacembalus armatus (Sharma 1981).

Gooding (1963) in Katsuwonus pelamis and Gemne and Doving (1969) in Lota lota observed total absences of cilia in supporting cells, but Yadav(1989) in Nandus nandus, O.bimaculatus, N.chitala and O.bacaila and Sharma (1981) in C.carpio, E denricus, H.fossilis, and M.armatus armatus observed cilia although fishes belong to different habit and habitat. The author has also traced out cilia in the supporting cells of all the three fishes Rita rita, Anabas testudineus and Macrognathus aculeatus of different habit and habitat. Bannister (1965) has not described cilia in Poxinus phoxinus and Gasterosteus but reported that free surface of these cells bears number of irregular micro villi.. The degree of ciliation depends upon the amount of work loaded on supporting cells. In the case of Rita rita and Macrognathus aculeatus water has to travel long distance in olfactory chamber and has to bath enormously developed olfactory surface, therefore, ciliation is predominantly developed and that too in clusters. In the

case of Anabas testudineus the cilia are of moderate type as workload is more on accessory nasal sacs and also olfactory chamber is sized and circular so the water has to travel short distance. Holl (1965) suggested that the non ciliated supporting cells isolates the receptor and contribute to the metabolism between the olfactory epithelium and blood, where as ciliated types act for the distribution of mucous on the epithelial surface. Holl (1965) and Pipping (1926) were of the view that ciliary activity of olfactory epithelium creates water current through the olfactory chamber.

De Lorenzo (1960) pointed out that supporting cells may be involved in the perception of the sense of olfaction in some way or other. But Kapoor and Ojha (1974) Ojha and Kapoor (1973) , Bertmar (1972) , Sharma (1981) Rahmani and Khan (1980) , Yadav (1989) have clearly distinguished supporting and receptor cells in the olfactory epithelium of fishes and also perfectly isolated their field of action i.e. former is supporting while latter as sensory components of the olfactory epithelium. Therefore, the supporting cells are meant for the maintenance of the integrity of the olfactory epithelium and to provide mechanical support to the dendrite of the receptor cells, keeping them erected in the position for

the reception of senses from the water current passing through the olfactory chamber. The inference can be drawn, from the foregoing discription that the ciliation is an integral part of the supporing cells. However it may disappear in some places where these cells are subjected with other effects, like muciferous activity of underneath pressure of flowing basal cells. It is also noted that the cilia of supporting cells are essential for drawing water current, while the cilia of receptors act as an antennae for reception of olfactory sensation form the circulating water. The other type of cellular projection like microvilli etc. are not of supporting cells but are the projection of the receptor cells.

The transitionary supporting cells have also been noticed in Anabas testudineus and Macrognathus aculeatus. Their major concentration is reported in the region of olfactory mucosa which are either under the pressure of flow of the basal cell in specific micro formation. They are also observed in the regions through which lamellar emergence is anticipated. Regarding the presence of transtionary supporting cell, finding were reported by Ojha and Kapoor (1973), Kapoor & Ojha (1974), Rahmani & Khan (1980), Sharma (1981), Yadav (1989) and Dubey (1991). But

Bertmar(1972) and Hara (1975) has denied the existence of transitionary supporting cells.

The receptor cells:

The sensory epithelium is characteristically provided with the elements which perceive sensation through the medium in which a particular organism exists . The sensory elements can be identified in the form of receptor cells which have got a long history of their investigation in the olfactory epithelium of teleosts by Aichel (1895) in Salvelinus alpinus, Coregonus worthmanni and Salmo trutis. The functional significance of the trigerminal ending is not well understood but they have shown to be odour sensitive in tortoise, Gapherus polyphinus and in Rabbits (Tucker 1963) . Stone et al (1968) suggested their significance in relation to olfactory inputs in Rabbit.

Singh (1972) observed that these receptor cells are uniformally distributed in young Bagarius bagarius, Xenantodon concila and Botio dario . Rahamani and Khan (1980) has also reported that receptor cells are almost uniformly scattered in young fish while in adult fish they are

in group and buried in depressions. The distribution of receptor cells in different pattern of olfactory epithelium is significantly variable. Iwai and Nakamura (1964), Malyukina et al (1969) . Yammato and Ueda (1977) observed great variability in the distribution of receptor cells with other components. Doroshenko and Motankin (1987) explored the variability in the distribution of cellular elements to the extents that the olfactory epithelium is distinct into receptory and indifferent epithelia. Singh and Singh (1986) distinguished ciliated cells (type one and two) , microvillus cells, pigment granules and rod cells in the olfactory epithelium of four hill stream fishes.

In the present investigation great variation in the receptor cells has been notice depending upon the nature of the olfactory epithelium. In Rita rita three types of the receptor cells; primary neurons, rod shaped and spindle shaped cells are regularly distributed, but there concentration can be seen in crupts and middle region of the lamellae. These cells are also found in the empty theca of marginal goblet cells, among the ciliated and non ciliated supporting cells and in the crupts formed by bursting of goblet cells. The irregular distribution of receptor cells can also be seen in cell

balls, curving, clubings, bulgings, funnel shaped inpushings, out pushing, depressions, flask funnel and tubular deepenings. In such formations the primary neurous and spindle shaped receptors are variedly supplied solitary or in groups, while in the proximal zone rod shaped receptors cells are observed. The olfactory epithelium of Anabas testudineus is also comprised of receptor cells. In young Anabas testudineus three types of cells are identified ; primary neurons , secondary neurons and spindle shaped receptors which are uniformly distributed, but in adult fish the distribution of receptor cells is not uniform, as they are grouped and buried in the depressions in between the secondary lamellae. In Anabas testudineus the dendrites are thin and of varying length depending on the depth at which they are situated. The axon of a receptor cells comes together near the basement membrane and joins to form folium olfactroium. The numbers of folia olfactoria are visible in the central core in the lamella of Anabas testudineus

In Macrognathus aculeatus the two types of receptor cells primary neurons and spindle shaped receptors are uniformly distributed except at the tip where it arranges in group. The receptor cells of Macrognathus aculeatus in the

thicker region of olfactory epithelium are deeply embedded, close to the basal zone and send their dendrite to the distal zone.

In all the three fishes primary neurons and spindle shaped receptor cells are traced out. In Macrognathus aculeatus primary neurons shows rich aggregation at the lamellar tips , making that area more sensitive, while in Anabas testudineus they are found grouped in depression or in between the secondary lamellae. In Rita rita they are abundant alongwith spindle shaped receptors and supporting cells in crupts and deepening, but are distributed uniformly at the periphery. In Anabas testudineus and Rita rita the deepenings are supplied with spindle shaped receptors while in Macrognathus aculeatus these cells are uniformly distributed. The dendrite of spindle shaped receptor cells in Macrognathus aculeatus and Anabas testudineus join together at the periphery and form olfactory cilia, while in Rita rita they establishing synaptic contact with the axon of primary neurons. The synapse has also been noticed in Anabas testudineus between primary neurons and secondary neurons, but in Macrognathus aculeatus no synapse is noticed. The synapse formation is an indication of

enhancement of olfactory reception capacity and may be described as advanced nervous character reported in the olfactory mucosa of Rita rita and Anabas testudineus .

The rod shaped receptor cells are found missing in Anabas testudineus and Macrognathus aculeatus , but in Rita rita they are commonly found in middle and distal region. The dendrites of these cells are thick and found extending in between the theca of two goblet cells or transvesing singly or in groups through the empty theca. The presence of rod shaped receptor cells in the olfactory epithelium of Rita rita is in accordance with the finding of Bertmar (1972) who reported three types of receptor cells in sea trout . Kolmer (1927) reported that rod and spindle shaped receptor cells are present in man. Neuhaus (1955) reported four receptor type in day. Bannister (1965) has described variations in the morphology of receptor cells in Phoxinus phoxinus. Holl (1965) was of the opinion that the two type (spindle and rod shaped) represent different ontogenetically stages. Bannister (1965) and Moulton and Beindler (1967) described them as the variation of one type resulted due to the tight packing of the cells. Dogiel (1887) , Morril (1898), Jagodowaski (1901) and Castello (1950) reported spindle, conical and columnar

receptor cells in frogs and fishes. Holl (1965) has described the rod and spindle shaped receptor cells in Salmo . He further reported the presences of spindle cells in all the teleosts studied by him, where as the rod shaped was only found in Salmo gairdneri, Salmo trutta fario, Esox lucinus, Pleuronectus platessa and Trigla coresx. Sharma (1981) reported rod shaped receptor cells in C.carpio and H fossilis, Primary neurons in M. armatus armatus , E. denricus and spindle shaped receptor cells in N.notopterus.Yadav(1989) observed concentration of primary neurons in the microformation of N.nandus. The olfactory epithelium of Rita rita and Anabas testudineus exhibits variety of microformations which are certainly filled with different types of receptor cells and meant for more reception , increasing the olfactory area on lamellar surface. In Rita rita microformations depends upon the muciferous activity of cells in distal zone and subsequently suppliment by the cellular bulk generated by the rapid morphogeneic activity , while in Anabas testudineus it solely depends upon the morphogenetic activity in the olfactory epithelium giving rise to greater bulk of cell. The formation of bud in the olfactory epithelium is a common feature in Rita rita which allows abundant accommodation to the receptor cells and it is

similar to the finding of Dubey(1991) in C. nama . Thus the efficiency of Rita rita , increases tremendously with respect to olfactory sense.

Ottoson (1963) , Yammato et at (1965) Moulton and Beidler (1967) , Kleerekoper (1969) , Graziadei and Metcall (1971) , Rahmani and Khan (1980) . They has described that receptors maintain in dependent identity and no synapses can be observed in the olfactory epithelium. Sharma (1981) observed independent receptor in C.carpio M.armatus and E.dendricus. Similar independent identity has been described by Yadav (1989) in Nandus nandus , O. bimaculatus and O. bacaila and by Dubey (1971) in C .nama and C . batrachus. The present author has observed the same finding in the case of Macrognathus aculeatus where no synaptic contact has been seen between two receptor cells.

Contrary to the finding of above workers, Ojha and Kapoor (1973) in Labeo rohita, Kapoor and Ojha (1974) in Channa punctatus, Sharma (1981) in N.notopterus and H.fossilis , Yadav (1989) in N.chitala and O.bimaculatus and Dubey in C.fasciatus reported secondary neurons or spindle shaped receptor cells in the olfactory epithelium which

establishes synaptic contact with primary neurons before reaching upto the mitral cells of the olfactory bulb.The same synapse has been reported in the present investigation of <u>Rita rita</u> and <u>Anabas testudineus</u>

Yammato and Ueda (1977) identified four types of receptor cells on the basis of surface specialization (i) The first type bear 10 to 30 relatively long cilia on a wide and flat surface, all the cilia of this type inclined in some directions over the wide range of the epithelium. This was called type one ciliated cells (latter they added that the cilia of the type one ciliated cells may be motile and might be associated with the circulation of fluid between the lamellae (ii) Type two ciliated cells have 8 to 12 short cilia which projects radially from the rounded apex of the cell (iii) In this type a tuft of 100 or more microvilli present but cilia thus called microvillus cells; (iv) The fourth is cell rod cell which neither bears cilia nor microvilli and its apical end protrudes as such . Bannester (1965) and Sehulte (1972) have also described type one ciliated sensory cells. Ichikawa and Ueda (1977) have found by the reterograde technique that type two ciliated cells and microvilli cells are genuine receptor cell, because when olfactory nerve is transected, only these two

type cells degenerated while the type one ciliated cell and rod cell remain enaffected. In the present study the author has traced out the cilia of receptor cells, from the cilia of supporting cells and is in a view that the cilia of supporting cells are stereocilia where receptors has olfactory cilia. The former are meant for circulating the water current thorough olfactory epithelium, where as latter for perceiving the sensation. This is in agreement by Jagadowski ((1981) , Vinnikob(1956),Trujillocenoz(1965),Bronshtein(1963,1965), Bannister (1965), Kleerekoper (1979) , Ojha and Kapoor (1973), Kapoor and Ojha (1974) , Hara (1975) Rahmani and Khan (1980), Sharma (1981), Singh and Singh(1986), Doroshenko and Motavkin(1987),Yadav (1989).

After the details study of receptor cells in all three fishes, the author is in the view that they are formed by the modification of basal cells and their different shape is for availing better advantage of sending their dendrite and axon to respective zones for receiving the sensation and ultimately transmitting it to the central nervous system for nervous analysis. The synapse establishment is an advance character and it enhance olfactory reception capacity, as well as prompt transmission of senses to central nervous system.

The mucous secretory goblet cells:

The aquatic mode of life in vertebrates is characteristically associated with the presence of goblet cells particularly in skin and number of sensory receptors, exposed to constant contact of the water, the fact of goblet cells association with aquatic habit has been explored by Whitaker (1970) in fishes, Farquhar and Palade (1965) in amphibians, Bannerjee and Mittal (1978) in aquatic snakes. The presence of mucus secretory goblet cells in aquatic forms is to minimize the friction between the body and water, thus increases the mobility of animal and also protecting the delicate mucosa by friction of water current . The mucous secretion in the olfactory chamber is through the mucosa of olfactory epithelium and accessory nasal sacs which performs the function of lubrication of the olfactory surface, as well as help in entangling the foreign material at one point and consequently removing it by outgoing water current, avoiding their deposition on olfactory mucosa regularly. The importance of mucus secretory goblet cells in the cellular constituents of the olfactory mucosa of the fishes has been reported by Kubiak (1962) in <u>Blicca byorkna</u>, Bennister (1965) in <u>Phoxinus phoxinus</u>, Pfeiffer (1963) in <u>Oncorhynchus</u>, Bertmar (1972) in <u>Salmo</u> , Singh (1972) in

Bagarius bagarius and Botia dario, Devitsyna (1972) in Gadus moruha , Eleginus novage and Lota lota . Ojha and Kapoor (1973) in Labeo rohita,Kapoor and Ojha (1974) in Channa punctatus, Sharma (1981) in Cyprinus carpio and Heteropneustes fossilis, Yadav (1989) in O.bimculatus, N.chitala Doroshenko and Matavkin (1987) in Limanda yolohamae and Dubey (1991) in C.batrachus.The detailed review of Kleerekoper (1969) and Hara (1975) also mentioned, olfactory mucous secretory activity in species of fishes.

In the present investigation the mucous secretory activity has been reported dominantly in Rita rita and Macrognathus aculeatus while in Anabas testudineus it is rarely noticed, though Rahamani and Khan (1980) in Anabas testudineus has reported the scanty presence of goblets cells, but author is in the view that as Anabas testudineus is a mud bottom dwelling most active fish, the presences of goblet cell is must for the flow of clean water.In Rita rita mucus secretory activity is noticed through out the entire length of lamellae, but it is found dominant at distal end, while in Macrognathus aculeatus this activity is present at terminal tips only. The absences of goblet cells is reported in

Xenentodon cancila (Singh 1972) , Hybapsis gelida and H.aestivalis (Branson 1963) and Colisa faciatus (Rahamani 1979) . Holl (1965) has described mucus cells in both in different and sensory epithelium of Salmo especially in those places where secondary foldings are present. Bertmar (1972) also reported mature goblet cells in Salmo which lies uniformly In surface zone of the indifferent epithelium but are scattered in sensory epithelium. Sharma (1981) in Cyprinus carpio and H.fossilis reported the rich distribution of goblet cells in the olfactory epithelium. The similar distribution has been noticed in Rita rita. On this basis the lamellae is divided into proximal and distal zone. The goblet cells are richly supplied in distal zone while in proximal zone they are restricted to a very short region. In Rita rita two types of goblet cell are traced out; marginal goblet cells and migratory goblet cells . The former cells are arranged at periphery and are produced due to the transformation of positively muciperous supporting cells with the age of the fish. The latter goblet cells are concentrated in the proximal or intervening region adjacent to the raphe and are originated from muciperous basal cells . The migratory goblet cells has the wandering tendancy from deeper to peripheral zone. Due to the fusion and bursting of goblet cells at periphery exposed

crupts are formed while in middle and at base unexposed types of crupts are formed . This activity of goblet cells makes the periphery wavy and more active towards the ecological changes in environment.

Similar to the finding of Sharma (1981) in E.denricus , Yadav (1989) in O.bacaila and Dubey (1991) in C.fasciatus, the goblet cells in Anabas testudineus are rarely observed in the mucosa of olfactory epithelium but they are restricted to the terminal lamellar tips and at the point of their emergence form the floor of olfactory epithelium.

In Macrognathus aculeatus the cells are found arranged at lamellar tips and make it more active, as in M.armatus of Sharma (1981). Besides this the formation of goblet cell bridge in posterior lamellae due to the excessive formation of mucus cells is also noticed. This is a specific finding which has not be reported in any fishes under investigation

In M.armatus (Sharma 1981) , Labeo rohita (Ojha & Kapoor (1973) and Channa punctatus (Kapoor & Ojha (1974) exhibit goblet cells in deeper zones of mucosa , but they discharge their content into the inter lamellar space. This

demonstrative migratory tendency of goblet cell from basal layer to supporting zone is for the purposeful discharged of their mucous contents into inter lamellar space for assisting the sensory perception , as well as for entangling foreign body circulating in the olfactory chamber alongwith water current. In air breathing vertebrates supra epithelial mucous layer dissolves the odorant particles to be smelled and wash away the material that has already been detected, so that first sample of air can be examined (Hildebrand 1974) . In fishes there is no need for the dissolution of material to be detected because it is already in liquid form and the constant flow of water washes away the material that has been detected, therefore the presences of large number of mucous cells in the olfactory epithelium in fishes could be explained by the fact that the secreted mucous form a boundary for the water flow in the olfactory epithelium (Zeiske et al 1976) The statement of Andres (1975) that in fishes the free surface of receptor cell is rinsed by water flow is not correct (Zeiske et al 1976). The mucous secretion is overlapped on the olfactory surface and thus perhaps help in smooth flow of water as well as isolating the unwanted foreign particles present within the circulatory water current in the olfactory chamber. Rosen and Cornford (1971) stated that slime

(mucous) has a remarkable capacity to decrease greatly the friction of water in the Pacific barracunda , Syphraena argentea for example the friction of water decreases by as much as 65.6%

Bloom and fawcett (1978) quoted that in mammals unicellular glands are the mucous secretory goblet cells which are distributed among the columnar cell in mucosa of different visceral organs. They further pointed out that goblet cells secrete mucous and are made up of an expanded apical end, filled with pale droplets of mucin. In the basal end compressed nucleus and small amount of deeply staining cytoplasm is present . The expanded cup shaped structure is known as theca which remain associated with the basal zone by a their base like stem . The nucleus and chromatin material along with cytoplasm is present in a shape of a knob or pin due to the high compression of mucin content filled in expanded theca.

In Rita rita , Anabas testudineus and Macrognathus aculeatus, the author has traced out similar structure of goblet cells in the mucosa of olfactory lamella as well as in the accessory nasal sacs as described by Bloom and Fawcett

(1978) . In Rita rita the theca is cup shaped with clearly visible nuleus and chromatin material which takes the shape of compressed structure. In Macrognathus aculeatus the goblet cells are beaked and wine cup shape in appearance. The nuclear contents are compressed but lie within the theca and not in the periphery as in the case of Rita rita.

In Anabas testudineus the structure of goblet cells is not very prominent . In the accessory nasal sac of this fish, large number of neckless goblet cells are visible which are scattered among cuboidal cells and become accumulated in a manner of goblet tree like out pushing and elevation.

Ojha and Kapoor (1973) , Kapoor and Ojha (1974) has described varying shapes and sizes of goblet cells with different phase of their secetory activity. In the present study the shape of goblet cells in Rita rita and Macrognathus aculeatus shows great variations, in former specie they are mostly enormous in size beaked and contributing a great bulk of supporting zone of lamellar mucosa, while in latter species goblet cells are beakless and projects beyond the surface of olfactory epithelium.

The author clearly observed migratory tendency in goblet cells in Rita rita and Macrognathus aculeatus . This is due to the fact that they are produced from two sources: first by the transformation of marginal supporting cells and second by the muciparous basal cells. In the latter case the basal cells along with its transformation into the goblet cell undergoes cyclic movement from basal to the supporting zone. This brought the goblet cells originated from basal cells to the free surface where mucous is discharged.

In Rita rita , the intervening region of the lamellae is pooled with muciperous basal cells, which under goes a process of transformation into the goblet cells, thus whole of the olfactory epithelium can be seen with different sizes of goblet cells, in the way of their migration from basal to supporting zone. In Macrognathus aculeatus the muciperious basal cells are present, but there transformation rate is less than that of Rita rita, while in Anabas testudineus no such transformation is visible.

In Rita rita the marginal goblet cells are resulted due to the continuous transformation of supporting cells in these cell types . As a result of this transformation whole of the

supporting zone is occupied by broad and elongated theca of goblet cells. This is in agreement with the finding of Moe(1955) who described the goblet cells as the modified columnar supporting cells. The transitionary stages of goblet cells can be seen in basal as well as in supporting zones.

In present study the attempts are made to classify goblet cells into two categories (1) Stationary goblet cells are produced by the marginal goblet cells and (2) Migratory goblet cells are produced by the muciperous basal cells which undergoes a course of migration from basal to supporting zone. The former category cells has ovoid cup shaped theca and opens directly from the free surface of the olfactory epithelium and can be named as "Marginal goblet cells" while latter with rounded and smaller theca are named as "Micro goblet cells.

In Rita rita the tremendous capacity of transformation of basal cells into goblet cells is seen which forms group and fuses at variable depths in the olfactory epithelium. Due to this activity of migratory goblet cells and inter cellular space created by the death of goblet cells, number of complex structures are formed in form of exposed and unexposed

crupts, curving, clubbing, elongation, bending ,elevation , depression of different shapes large number of receptor cells accommodates. The cellular gaps created by the death of goblet cells in the supporting zone helps in providing the way for the migration of basal cells leading to the formation of finger like out pushing, bulging, knobbing, clubbing, detachment, bifurcation and other forms. In this way the area of the sensory epithelium of Rita rita greatly increases, which help them to cope up with changed environmental condition. The crupts along with the sensory elements appears like a well formed olfactory bud, which found embedded at different depths in the olfactory epithelium.

In 1972 Bertmar has denied the possibility of grouping of goblet cells in the olfactory epithelium. Bloom and Fawcett (1978) quoted that the secretion of mucus proceeds more or less continuously, which ultimately vacant the cells body and lead its death. The span of mucus secretory goblet cells may be two to four days in the intestinal mucosa, although goblet cells normally passes through only one long secretory cycle, but they may be made to expel all of their secretion at onces.

Vinnikov (1965) thinks that mucous layer contributes in the active reception of olfactory senses, which is further justified due to their identification in macromatic forms such as L.rohita (Ojha & Kapoor (1973) ; C.punctatus (Kapoor and Ojha 1974) , C.carpio , H.fossilis , M. armatus (Sharma (1981) , O. bimaculatus and O . bacaila (Yadav (1989) Clarias batrachus (Dubey 1991) and L. gonius (Singh (1992) which exhibut dominating olfactory response in the discharge of vital activities such as schooling, defence, meeting , location of breeding and feeding places.

Devitsyna (1972) studied two marine fishes Gadus morhus , Elaginus novaga and one fresh water Lota lota . He concluded that goblet cells can be assumed in some way to promote the olfactory active substance in the salt water. But author contradicts Devitsynas (1972) view point as goblet cells are present in the olfactory epithelium of active Rita rita , Anabas testudineus and Macrognathus . aculeatus which are fresh water fishes. The association of the goblet cells with aquatic mode of life can be traced out as they are present in fishes (Whitaker 1970) , amphibians (Farquhar and Palade 1965) end aquatic snakes (Banerjee and Mittal (1978) . The author is in the opinion that mucus secreted by

goblet cells is to minimize the friction between body and water, which increases the mobility of the animal, it protects the sensory epithelium with direct effect of water current and also help in sensation and removal of debris by entangling it, Beside this it play important role in fish life , as it helps them to increase the olfactory area.

The basal cells :

Universally in the mucosa of all the visceral organ, mother cells are present called Basal cells. These cells latter on converts into other cellular components required in the composition of a particular endodermal tissues. The basal cells characteristically lies above the basement membrane in a variable number and amount performing morphogenesis and transfer of nutritional contents from submucosal to mucosal region (Ross and Reith 1985) . The presences of basal cells just above the basement membrane has been reported by Allison (1953) , Graziadei (1965) , Andres (1966) , Wilson and Westerman (1967), Gemme and Doving (1967) , Singh (1972) , Bertmar (1972) , Ojha and Kapoor (1973) , Kapoor and Ojha (1974) , Hara (1975) , Zeiske et al (1976) , Branstein (1976) , Yammato and Ueda (1977) ,

Rahamani and Khan (1980) . These cells distinctly give rise to supporting cells Schaeffer(1932) . Cordier (1964) , Ojha and Kapoor (1973) or to receptor cells Andres (1966) , Thornhill (1970) , Graziadei and Metcalf (1971) to both type of the cells Bertmar (1972), Hara (1975) , Sharma (1981) , Singh and Singh (1986) Wilon et al (1986), Yadav (1989) and Dubey (1991) .

In the present study of the olfactory epithelium of Rita rita, Anabas testudineus and Macrognathus aculeatus, basal cells are found arranged in a variable manner above the basement membrane. In Rita rita the basal cells are found irregularly lying above the basement membrane. In the proximal and middle region of the initial and middle lamella , the basal cells are sparse and scanty , while in distal region of all lamellae and in hinder lamella they are irregularly arranged . In Rita rita basal cell shows their flow into the terminally detached cell balls in middle lamellae and in posterior lamellae they flow to form bud. The bud and detached cell balls are richly supplied with the basal cells, which may transform these fragments into complete lamella or provide nutritional supply to the other part of the olfactory epithelium.Beside this, they are found richly present in

elevations which ultimately give rise to minor lamellae and in different types of crupts, bending, bulging, deepening and olfactory bud which are formed due to the bursting of goblet cells and subsequently by the migration of basal cells in direction of formation of specific microstructure for the increase of olfactory metabolic surface area.

In Macrognathus aculeatus the basal cells are arranged in three to four layers just above the basement membrane and are also found aggregated in proximal region at some places adjacent to the floor of the lamellae. In Macrognathus aculeatus the basal cells are muciperous and undergoes a cyclic migration from basal to supporting zone in the preparation of the formation of complete goblet cell, which discharge their mucous secretion at the free distal surface of olfactory epithelium.In Macrognathus aculeatus the flow of basal cells at periphery is observed where they multiply rapidly and increases the surface area and also transferring into supporting cells. This is an agreement with the statement of Kolmer (1927) , Schaeffer (1932) and Cordier (1964). According to these workers the basal cells are additional or younger form of supporing cells which may be ultimately replaced the latter in the olfactory epithelium.

The raphe of Rita rita and Macrognathus aculeatus bears a clear basal zone which is constituted with one or more layers of basal cells.

In Anabas testudineus the basal cells are present in great bulk at the inter lamellar junction and in the secondary lamellae. In Anabas testudineus the basal cells undergoes frequent mitosis, which give rise to hillock elevation and the secondary lamellae in the shapes of cuneiform , filiform and fungiform structures, depending upon the flow of basal cells in that particular region. Thus in this fish the basal cells does not exhibit muciperous activity but reciprocate its independent identity. This is in accordance with Rahmani and Khan (1980) and Dubey (1991). Thus the surface migration of basal cells in Rita rita is distinctively demonstrated . Such demonstration of basal cells displacement is also reported in H. fossilis, C. carpio (Sharma 1981) , N. nandus and O. bimaculatus (Yadav 1989) and C. batrachus and C. nama (Dubey 1991). The basal cells are observed in the accessory sacs of Anabas testudineus, Rita rita and Macrognathus aculeatus which give rise to the formation of hillock elevation in the internal lining of the sacs . The goblet cells and cuboidal supporting cells are also continuously replaced

by basal cells. In Rita rita these cells are arranged in three to four layers above basement membrane and at some place they accumulate to form hillock elevation In ventro lateral accessory sac, while in Macrognathus aculeatus these cells are abundantly present in the tree like projections, where they ultimately transfer into goblet cells. The presence of basal cells has also been reported in C.carpio and M.armatus(Sharma 1981) and N. nandus and N. chitala (Yadav 1989). In Anabas testudineus these cells are supplied more in ethmoidal sac while they arrange in two to three layers in lacrymal sac.

The pigment cells:

In the cellular composition of receptor surfaces like hearing, olfaction , taste and touch are represented peculiarly by dark staining cellular mass known as pigment cells. Though the function of pigment cells is not fully known, but they are supposed as a sign of enhanced power of smelling and hearing in some vertebrates in some way or other (Allison, 1953) , It is significantly noted that albino animals in which pigment cells are lacking are particularly liable to poison. Malyukina et al(1969) thought that there relationship

between the intensity of colours of olfactory epithelium and the sensitivity of the organ of small, darker the epithelium higher the sensitivity . Hilde brand (1974) has favoured the view that pigment may enhance the olfaction in some unkown way. Sharma (1981) observed pigment cells in M.armatus , H.fossilis , N.notoperus, and C.carpio . Singh and Singh (1986) n Barilius bendelished Schizothorex richardsoni and Puntius chilinoder, Yadav (1989) in O.bimaculatus, N.chitala and O.bacailla , Dubey (1991) in Chanda nama , C.batrachus and C. fasciatus and D.P.Singh (1972) in L gonius .

In the present study the pigment cells are reported in Macrognathus aculeatus while in Rita rita and Anabas testudineu rosettes at some places only these cells are traced. In Macrognathus aculeatus the olfactory rosette is coated with thick sheath of pigment cells, which are found impregnated in the connective tissues fibres. The blood vessels and nerves running along the barrel shaped rosette and accessory sac are also encircled by the pigment sheath in Macrognathus aculeatus

Devitsyna (1972) on the basis of comparative study of three ganoid fishes concluded that pigmentation of olfactory plates is a characteristic feature of some species with a reduced olfactory function . Navaoa eleginus wears pigment cells while Lota lota and Gadus morlua are devoid of these cells . Sharma (1981), Yadav (1989) and Dubey (1991) contracted the idea of Devitsyna (1972) as they observed pigment cells in C. carpio , H. fosslis, M.armatus (Sharma (1981) , O. bimaculatus , N. chitala and O. bacaila (Yadav 1989) , Chanda nama (Dubey 1991) all these speices were represented with dominant olfactory development and were placed in the category of macrosmates.

The present author is in the opinion, that though physiological mechanism of odor receptor is not known, but pigmentation have been found in the olfactory epithelium and it is assumed that this pigment helps in transferring (or promoting enzyme catalyzed reaction which eventually give rise to) nerve impulses along the olfactory nerve.

Histoecological variations

The vertebrates are significantly organized by the highly developed nervous system and behavioral response are totally dependent to it. The development in the relative size of the olfactory bulbs, lobes, optic tactum reflects the degree of development of olfactory and visual receptions. Danis and Miller (1967) also observed that the development of sensory lobes reflects hypertrophy of peripheral sensory mechanism. In the Carpsucker, Carpiodes velifer (Miller and Evans, 1965) , for example due to great development of teste bud in mouth and palatal organs, the vagal lobes are large. On the other hand, Evans (1935, 1952) reported that in Gadidae, cyprinidae, catostomidac, where external taste buds are numerous, the facial lobes become enlarged. Thus the relative development of different lobes of brain may reveal to some extent the degree of development of different faculties. Therefore, macrosmatic fish must have large olfactory lobes and bulbs but have comparatively poorly developed optic lobes , while the microsmatic ones must have just the reverse conditions.

The procephalon is related to olfaction , mesencephalon to vision and the rhombencephalon to taste, equilibrium and lateral line system (Parker and Haswell, 1951; lagler et al 1962) . Nevertheless the brain of teleosts has undergone a great modifications, indicating its suitability in accordance to morphology and sensitivity of different faculties.

The ecological co- efficient calculated by the relative lengths of the telencephalon and mesencephalon and by the areas of the olfactory rosette and the retinae, has given the distinctive results, which has helped in illustrating microsmatic, macrosmatic and mesomantic nature of fishes under present investigation. The detailed illustration are recorded in the Tables 1, 2 and 3. In Rita rita the area of two rosette and taken telencephalon is considerable higher than that of area of two retinal and length of mesenecephalon (Table 1), identifying it as a " macromatic fish". The Macrognathus aculeatus is also considered as " macrosmatic fish", because the values (table 3) of telenaphalon and area of two rosette is higher than that of mesenceihalon and area of both retinea. In the case of Anabas testudineus the area of two rosette is higher, but the value of the areas of two retina cannot be ignored (table 2) . The optic and olfactory faculties

from the area point of view exhibit significant valuation, with telencephalon little higher than mesencephalon. All these calculations determine Anabas testudineus as "mesosmatic fish" where both the faculties are of significant value. Hence this fish be identified as "mesosmatic fish" or " eye nose" fish.

Keeping in consideration the above values in relation to length and area measurements, histoecological findings also contributes a lot in confirming above justifications. In Rita rita and Macrognathus aculeatus the macrosomatic nature is further evaluated by the presence of numerous lamellae.

In Rita rita numerous microformation on the lamellar surface in form of curbing, clubbing, budging, funnel shaped mucosal inpushings, outpushings, tubular, flask shaped deepening, elongation of lamellae, bending of lamellar tip in "U Shaped" budding, bifurcation, crupts, bud and formation of "cell balls" also shows its macrosmatic characters, as these are the device for increasing the olfactory surface, accommodating more receptor elements in the mucosal regions for prompt and efficient reception of olfactory sensation . In Rita rita the initial and middle lamellae are

found richly supplied with goblet cells. Due to the bursting of these cells, different types of deepening are seen on lamellar surface, while the flow of basal cells in that region give rise to hillock elevation, which ultimately changes into bud. On the bases of location, the terminal and basal buds are noticed in this fish. The bursting or fusion of goblet cells at different depths also give rise to exposed crupts at periphery and unexposed crupt in middle and base. In Rita rita basal, median and terminal bifurcations are also seen in specified lamellae and at some places the fusion of mucosal area of minor lamella with mother lamella is noticed, giving rise to unexposed crupts of variable shapes and size. The intra cellular spaces are created in mucosal surface due to the death of goblet cells , after the total discharge of mucus and the flow of basal cells in these spaces causes the creation of number of microformation. This demonstrate histoecological features in Rita rita .

The unique feature noticed in Rita rita is the turger of lamellae due to the extension of raphe, which helps in keeping lamellae erected in olfactory chamber during the course of water circulation, allowing perfect and prompt

involvement of sensory surface with reactionary contents in water .

In Macroganthus aculeatus beside numerous lamellae, it is observed that at some places submucosa send its off shoot to periphery , with the flow of basal cells in that direction. It is assumed that this activity in lamellae is meant to increase the olfactory surface in the change environmental conditions for efficient reception. The presences of dominant goblet cells at posterior lamellar tip forming a bridge between opposite lamella is also an ecological modification. The presence of enormously elongated barrel shaped rosette in Macroganthus aculeatus also demonstrate histoecological adaptation which is further confirmed with enveloping in thick pigment sheath and dominant muciferous activity in olfactory epithelium .

In the case of Anabas testudineus the number of lamellae are less, so to cope up with changed ecological condition each lamellae in itself act as a single rosette. Though the microformation are limited , but lamellar surface are richly supplied with hillock elevations which ultimately give rise to secondary lamellae. These secondary lamellae

may in cuneiform , filiform and fungiform shapes and are supplied with submucosal off shoot. This leads in increasement of lamellar surface. This justify that inspite of less number of lamellae Anabas testudineus as an 'eye nose' fish , operating both the faculties efficiently in discharging its most active predatory habit in a prevailing atmosphere .

On the basis of the evaluation of macrosmatic and mesosmatic nature of these fishes , author attempted to co-relate this habit with these sensitivities.

Rita rita and Macrognathus aculeatus are macrosmatic fishes, as they live at murky depths in water bodies and exhibits nocturnal habit. Thus these fishes searches their food which are mainly insects, worms, algal matter etc on the basis of odour, emitted by the preys or food object. This character is in accordance with feebly developed optic faculty and significantly developed olfactory faculty searching food object and prey in darkness at bottom.

As Anabas testudineus is an 'eye nose' fish, using both the faculties very efficiently (eye and nose) in searching the prey and recognizing fright reaction. Though

this fish is a bottom feeder with voracious carnivores acting as predatory fish mostly in quite or stagnant water, but it usually comes to the surface for gulping the air. Such activity justified its mesosmatic cadre and histoecological adaptations matching to its life activity .

The present author is with the positive view of Sharma (1981) , Yadav (1989) and Dubay (1991) that irrespect of macrosmatic and mesosmatic nature of fishes under study, the function of optic faculty cannot be ignored , though its degree of efficiency varies with respect to above mentioned characters . Except for the fishes of abyssopelogic zone of the sea, dark caves and very turbid water where vision is minimum or nil, most of the fishes utilize both vision and olfaction for day to day life.

Summary

SUMMARY

A comparative histoecological study of the olfactory epithelium of three fresh water live fishes Rita rita, Anabas testudineus and Macrognathus aculeatus has been described. The olfactory chamber in all three fishes lies on the dorsolateral surface of the head. The position of olfactory chamber is close to the eye in Anabas testudineus, while in Rita rita it is close to the snout and away from eye orbit. In Macrognathus aculeatus it is typically elongated covering whole of the snout holding out extreme terminally on both side of the fleshy rostral appendage.

The olfactory chamber in all the fishes under investigation communicates outside by an incurrent, anterior and an excurrent porterior nasal opening. Both nasal opening in Anabas testudineus lies very close to each other but in Rita rita at a considerable distance, while in Macrognathus aculeatus pores are situated at the two extremities of the elongated snout forming trilobed rostral projection.

The anterior nasal pore in Anabas testudineus and Macrognathus aculeatus is in form of a tube, which is

anteriorly and forwardly directed . In Rita rita the anterior nasal opening is spherical,while the posterior one is oval shaped and is covered by a nasal flap, which extends anteriorly upward forming a short nasal barbel. In Anabas testudineus posterior nasal opening is circular, while in Macrognathus aculeatus it is slit like aperture.

The olfactory rosette shows a great variation in shape, size and number of lamellae in all the three fishes under study . In Rita rita bean shaped , in Anabas testudineus quadrangular and in Macrognathus aculeatus barrel shaped rosette are found lying in olfactory chamber. The olfactory rosette of former specie bears an elongated raphe dividing it into two equal halves, while latter two species are rapheless . In Macrognathus aculeatus rosette is made up of dorsal and ventral halves , fitted with each other by their lateral hinges . The olfactory , epithelium throws out finger like projections called lamellae . The number of lamellae varies from 7-10 in Anabas testudineus , 80-110 in Macrognathus aculeatus and 89-175 in Rita rita . In Anabas testudineus single type of lamellae are only found having diminutive out growths on the peripheral surface, which ultimately give rise to fungiform , cuneiform and filiform type of secondary

lamellae, but in Rita rita and Macrognathus aculeatus three types of lamellae are noticed on the basis of their cellular composition and structure. In Macrognathus aculeatus pointed tip posterior, expanded tip anterior and mixed tip middle lamellae are noticed, while in Rita rita initial, middle and hinder lamellae are identified on the bases of their cellular composition. The initial and middle can be differentiated in the proximal, middle and distal zones. The proximal and middle zones are composed of columnar ciliated supporting cells with rich supply of spindle shaped cells, while the latter one is of nonciliated supporting cell intermingled with goblet cell. The hinder lamellae don't show zonal demarcation and are uniformly lined by the nonciliated cuboidal supporting cells, with enormously developed submucosa.

Histological observation reveals that lamellae in all three fishes (Rita rita ; A.testudineus and M.aculeatus) is made up of central core or submucosa , lined on either side by the cellular layers of mucosa. The basement membrane stands as partition in between submucosa and mucosa .The cellular composition in the above mentioned fishes varied

greatly in co-ordination with the ecological encounters in the prevailing environmental conditions.

The mucosa of all the three fishes under investigation is mainly constituted of supporting cells, receptor cells, mucous secretory goblet cells and basal cells. The olfactory epithelium of lamellae in all three fish shows great variation in composition and number of microformations. These variations can be regarded as histoecological modification in all the three live fishes.

The olfactory epithelium of Rita rita is provided with number of microformations such as hillock elevations, straight projections,bifurcation, curving,deepening, budding , swelling and crupts of variable shape and size lying embedded at different depths in the olfactory mucosa. The crupts accommodates large number of primary neurons and open through the surface of lamella , forming a well defined "sensitive area". All these microformations leads to increase the area of olfactory surface.

In the olfactory epithelium of Rita rita migration, grouping and bursting of goblet cells is seen. This activity

of goblet cells causes the displacement of basal cells which may flow in any direction leading to microformations. The rupture of goblet cells in groups, give rise to olfactory crupt in mucosa through which primary neurons and spindle shaped receptor cells protude out their cilia, giving an impression of olfactory sensitive zone. In Rita rita two types of crupts are noticed on the bases of their location, at periphery the exposed crupts, while in middle and at base unexposed crupts. The unexposed crupts are also formed due to the mucosal fusion of minor lamella with mother lamella.

In some specified lamellae of Rita rita there occurs accumulation of some mucosal contents, which lead to create lateral lamellar bud and terminal detachment in from of composite cell ball. The bud and cell ball is provided with olfactory submucosal content and they get merged with recipient lamella, substituting readymade supply of submucosal zone, consequently enhancing lamellar capacity.

Beside these histoecological pecularities there is also reported basal, medial and terminal bifurcations, where submucosa sends its off shoot, which increases the olfactory receptive.

In A. testudineus it is noticed that the number of lamellae are less, but to cope up with diverse ecological conditions, its basal cells shows morphogenetic activity. These cells get multiplied rapidly and start flowing towards the periphery alongwith submucosal support forming cuneiform , filiform and fungiform type of secondory lamellae and acute hillock elevation and deepening. This functional activity is nutritional and supported by blood supply present in mucosa of activated region demonstrating histoecological activity in the olfactory epithelium of this fish. In M.aculeatus the compact cellular organization is seen, but sometime to survive in changed environmental conditions its submucosa exhibits morphogenetic activity, resulting the flow of cellular contents towards the periphery. Due to the migration of basal cells the mucosal surface increases. Beside this, typically elongated rosette with deep pigment enveloping and successive presence of large number of lamellae on both side of lumen is in compensation with its mud hole dwelling nocturnal habit .

In all the three fishes Rita rita , M.aculeatus and A. testudineus , two types of supporting cells, the ciliated and

nonciliated are traced out . The latter in Rita rita is seen at distal region of initial and middle lamellae, while it is the main constituent of hinder lamellae and in A. testudineus they are dominantly found in elevations. In M.aculeatus they are found arranged in the second row of mucosa. In the latter two fishes, nonciliated supporting cells also act as transtionary cells which give rise to goblet cells. The ciliated supporting cells in Rita rita are found confined in proximal and middle region of initial and middle lamellae only, while in A.testudineus they are found at interlamellar junction and slopes of fungiform secondary lamellae. In M. aculeatus the ciliated supporting cells are situated at periphery.

In the olfactory epithelium of all three fishes, different types of receptor cells are noticed. In M. aculeatus the primary neurons and spindle shaped receptor cells, in Rita rita primary neurons, rod shaped and spindle shaped receptor cells, while in A.testudineus primary neuron, secondary neuron and spindle shaped receptors are indentified. In the former fish no synaptic contact is observed, but in Rita rita and A.testudineus the synaptic contact is seen between primary neurons and spindle shaped receptor cells, and between primary neurons and secondary neurons

respectively . The establishment of synapse in between any two receptor within mucosa provide prompt and strong sensory transmission making fishes more effective in olfactory receptions substituting they habit and habitat accordingly.

In A.testudineus, Rita rita and M.aculeatus the dendrite protrude in inter lamellar space in variable shapes and sizes known as olfactory cilia. In case of Rita rita they are elongated, while in M.aculeatus they are mostly seen as solitary projections. In A.testudineus the projection of dendrite in inter lamellar space is inconspicuous, but in secondary lamellae and elevation their prominent projections are seen.

The goblet cells are prominently visible in Ria rita in all zones of mucosa, while in M.aculeatus they shows their dense accumulation on terminal tips of lamellae. The migratory tendency of the goblet cells can be seen in the olfactory epithelium of these fishes , where they are mostly produced by basal cells and undergoes a cyclic movement from basal zone to supporting zone for mucus discharged. In Rita rita goblet cells creates intra cellular space the total

discharge of mucus content, through which rapidly multiplying basal cells find their way in diverse condition causing the creation of microformation, lamellar bifurcation and crupts. In M.acuteatus their rich aggregation at the terminal tips of posterior lamellae give rise to goblet cell bridge between two opposite lamellae oblitating posterior part of the lumen. The accessory sac of Rita rita, A. testudineus and M.aculeatus are provided with dense mucus secretory epithelium possesing moderate size goblet cell which support the action of accessory nasal sac in all the three fishes for lubricating the olfactory passage entangling foreign unwanted particles. In A.testudineus mucous secretory goblet cells are very scanty but their existence is rarely observed at some tips . The aggregation of basal cells is reported in Rita rita , A.testudineus and M.aculeatus at variable depths of mucosa, giving impression of their transformation in other cellular constituents of the sensory epithelium, at the time of diverse ecological conditions, or to repair or replace the damaged or worn out part of the mucosa. Basal cell in all three fishes form distinctive basal zone just above the basement membrane but they are distributed indifferent amount of bulk in fishes under study. In A testudineus rapid multiplication in the basal zone is seen

under the nutritional , nervous , connective tissue and support of submucosa forces them to migrate at periphery in gradual suscation, causing emergence of secondary lamellae , hillock elevation and depression on mucosal surface. In Rita rita basal cell morphogenetic activity and moderate multiplication direct their migratory way through intra cellular spaces form by the total discharge of mucus by goblet cells. This causes creation of elevation , depression , bending , curving , terminal detachment and cells ball formation . All such emergence lead to increase the olfactory reception area .

In Rita rita ; A.testudineus and M.aculeatus the pigment cells are reported and can be assumed that they help in transferring nerve impulses along the olfactory nerve. In M. aculeatus the thick pigment sheath encircling the whole rosette is visible, while in A.testudineus and Rita rita they are found submerged in the connective tissue fibers.

In all three life fishes accessory nasal sac are found . In In Rita rita ventro lateral accessory nasal sac, in A. testudineus ethmoidal and lacrymal accessory nasal sac and in M. aculeatus anterior accessory nasal sac and infra nasal

chamber are found. These sac are having submucosal and mucosal zone with blood, nervous , connective tissue and macrophage system supply . The mucosa is most secretory and non receptory possessing a good bulk of round goblet cells , cuboidal supporting cells and two three layers of basal cell. Mucus secretion is dominantly present in all the three fishes and some time goblet cells accumulates in elevation showing tree like projections. They are pumping apparatus and reservoir of water during the course of water circulation through olfactory chamber. They secret mucus accessibly which support to lubricate whole of the respiratory passage.

The flow of water current through the olfactory chamber is unidirectional in all the three fishes, which is created by the anteroposterior beating of cilia. Beside this the water current is also drawn in due to the compression and expansion of ventro lateral accessory sac in Rita rita , by ethtmoidal and lacrymal accessory nasal sac in A.testudineus and by anterior nasal sac and infra nasal chamber M. aculeatus.

The ecological co-efficient is calculated by the area of two retinae, two rosette and by the length of telencephalon and mesencephalon . It is seen that A. testudineus is a " eye – nose" fish where both the faculties are well developed. Rita rita and M. aculeatus are macrosmatic forms, where only olfactory faculty is well developed.Macrosmatic M.aculeatus and Rita rita are nocturnal and found inhabiting at murky depths, while A. testudineus being "eye nose" fish leads an active life both in day and night hours, displaying its efficient dependency on both optic and olfactory faculty , acting as voracious carnivores and most active live fish in the environment . M. aculeatus is a mud hole dweller and mostly depends on dark bottom on olfactory faculty in searching food responding to other defense behavior. Rita rita being a macrosmatic fish and possessing more histoecological formation on lamellar surface acts dominantly in demonstrating its defense , schooling and reproductive behavior.

Bibliography

BIBLIOGRAPHY

Aichel,O.(1895) Kurze Mitteilunguber den histologischen Bauder Riechschleimhaut embryonule rteleostier .Sit.Ben.Ges Morphol. 11.73-78

Allison,A.C.(1953) The morphology of the olfactory system in vertebrates. Biol. Rev. Cambridge Phil. Soc. 28: 195 - 244.

Andres,K.A.(1966) Der Feinbau der Regio olfactoria von Makrosmatikern. Z. Zellforsch.69: 140-154 .

Bannerjee,T.k and Mittal, A.K(1978). Epidermal mucous cells in the Chequered water snake, Natrix piscator(Colubridas:Squamata): A cytochemical investigation. Zool. Jour.Linn.Soc 63:289-293 .

Bannister,L.H.(1965). The fine structure of the olfactory surface of Teleostean fishes Quart. J. Microscap Sci 106:333-342.

Bashar,D.P,Beuerman,R.WandEaston,D.M.(1974) Ciliary action and normal movement of odorant wave fronts in garfish nasal capsule of Lepisosteusosseus. Experientia, 30:777-779.

Bateson, W. (1889). The sense organ and perceptions of fishes with remark on the supply of bait. D.Mar. Biol .Ass 1:225-256

Bertmar,G.(1965). The olfactory organ and upper lip Dipoi, embryological study. Acta. Zool. (stockh). 46: 1-40

Bertmar, G. (1972 a). Scanning electron microscopy of olfactory rosette in Sea Trout .Z. Zellforsch. Mikroskop . Anat . 128:336-346

Bertmar,G.(1972 b). Secondary folding of olfactory organ in young and adult Sea Trout. Acta. Zool. 53:113-120.

Bertmar,G.(1972 c). Ecostructural studies on olfactory organ in young and adult Sea Trout .Z. Morphol. Oekol. Tiere 72: 307-330

Bertmar,G.(1973). Ultra structure of olfactory mucosa in the homing Baltic Sea Trout. Salmo trutta trutta. Marine. Biol 19:74-88.

Blaue (1884). Arch.F.p.241 (Quoted by Burne, 1909).

Bloom, G. (1954). Studies on the olfactory epithelium of the frog and the toad with the aid of light and electron microscopy. Z. Zellforch. 41:89-100.

Bloom, William, M.D. and Fawcett Don.W, M.D(1978). A text book of histology. Tenth Ed. Asian Ed. W.D. Saunders Company, IGAKU SHOIN Ltd. Tokyo, 990 pp.

Branson, B.A. (1963). The olfactory apparatus of Hybopsis aestivalis (Girard). (Pisces: Cyprinidae) J.Morphol. 113:215-229.

Bronshtein,A.A and Ivanov, V.P(1965) electron microscopic investigation of the olfactorial organ in the lamprey . J. Evol. Biochem. Physial: 251-261.

Burne, R.H.(1909). The anatomy of the olfactory organ of the teleostean Fishes.Proc. Zool. Soc (London), No 2:610-663.

Calzada, A.Medina, A. and Canales, DE,Gonzaliz, L.M.(1998) fine structure of the intestine development in cultured sea bream larvae. J.fish Bio 340-365. Articles no. jb 980703.

Castello, R. (1956). Effetti della neurotossicita day streptomicina edudrostreptomicina sulla funzione olfattive. Minerva otorinolaring 6:129-135.

Copeland, M. (1912) The olfactory reaction of the puffer or swell fish Spheroids maculates (Bloch and Schneider) J. Exp. Zool.12:363-368.

Cordier, R. (1964). Sensory cells in The Cells volume iv[th] Brachets and Mirsky Editors, Academic Press Newyork.

Davitsyna,G.V.(1972) Morphology of the organs of the olfaction in the Gadidae. J. Ichthyol 12:994-1002.

Delorenzo, A.J.D. (1957) Electron microscopic observation of the olfactory Mucosa and olfactory nerve. J.Biophys. Biochem Cytol. 3:839-848.

DeLorenzo, A.J.D(1960). Electron microscopy of the olfactory and gustatory pathway. Ann. Otol Rhinol. Laryngol 59: 410-420.

Derivot, J.H. and Godet, M.D.R.(1979) Anatomic fonctionnelle de l'organe olfactif de Protopterus annectens Owen (Dipneustes):contributiona'laconnaissanc edu mecanisme d'irrigation de'l'organe olfactif., Acta. Zool (Stockh) 60: 251-257.

Devitsyna, G.V.(1972)Morphology of the organs of olfaction in the Gadidae. J.Ichthyal 12: 994-1002.

Dogel, A.S.(1886) Stroenic obonyatel nogo organa u ganoid Kostnykh rybi amfibii (Structure of the olfactory organ in the ganoids of the bony fishes and amphibians). Tr. Obshch. Estestvozn. Pri. Kazansk. Univ. 16

Dogiel, A(1887). Uber Den Bau des Geruchsorganis beri Ganoiden. Knochenfischen und Amphibian Arch. Mikr. Anat 29: 74-139.

Doroshenko, M.A and Motankin, P.A.(1987) Surface structure of the olfactory organ in marine teleost

fishes. ARKHNAT. GISTOL. EMBRIOL. 91(10): 38-47.

Doving, K.B and Thommesen, G.(1977). Some properties of fish olfactory system. In olfaction and taste vi. Paris. 1977: 175-183.

Doving, K.B. Dubois Dauphin, M, Holley, A and Jourdan,F(1977) Functional anatomy of the olfactory organ of fish and ciliary mechanism of water transport. Acta. Zool(Stockh) 58: 245-255

Dubey, S.K.(1991) A comparative histological study of the olfactory epithelium of some fresh water fishes Ph. D. Thesis(P.P. 1-207), Bundelkhand University, JHANSI INDIA.

Eaton, T. H. Tr(1956) Notes on the olfactory organs in Centrachiadae. Copeia. No. 3: 196-199.

Farquhar, M.G. and Palade, G.E.(1965) Cell junctions in amphibians skin. J. Cell. Biol. 26: 263-291.

Frisch, K. Von (1941) Uber einen Schreckstoff der fisohhault and scine biologische bedutung. Z. Vergl. Physical. 29.

Frisch, D (1967) Ultrastructural of mouse olfactory mucosa. Am. J. Anat. 121: 87-120.

Gautam, R.K. and Gautam Kalpana Pesticides alter enzymes in gastro intestinal tract of channa punctatus Aquacult 1(2) , 167-170,2000.

Gautam . R.K., and Gautam Kalpana Pesticides alter biochemical constituent of stomach and intestine of Channa punctatus. J.Exp. Zool . India Vol. 4 (2) , pp.,2001

Gemne, G and Doing, K.B. (1969) Ultrastructural properties of primary olfactory neurons in fish (Lota lota L.) Am. J. Anat. 126: 457-476.

Gerebtzoff,M.A. et Shekapenko,G(1952) Researches sur le pigment de la muqueuse olfactive. C. R. Ass. Anat 38. Reunion Nancy 1951. Fasc. 68: 511-516.

Gooding, R.M.(1963) The olfactory organ of the skipjack Katsuwonus pelamis. F.A.O. fish. Rep; 3: 1621 – 1631.

Graziadei, P.P.Cand Metcalf, J.F (1971)Autoradiographic and ultrastructural observation on the frog's olfactory mucosa. Z. Zellforsch; 116:305-318.

Grimm, O. (1873) Ob Okonchanu nervnykh volokon v obonyatel nom organe osetrovykh ryb (The terminals of the nerve fibers in the olfactory organ of sturgeon). Tr. St. Peterb. Obshch. Estestvoisp. 4(1).

Hagelin, L.O. and Johnels, A.G.(1955). On the structure and the function of the accessory olfactory organ in lampreys. Acta Zool(Stockh) 36:113-125.

Hara, T.J. (1975) Olfaction in fish. Prog. Neurobiol 5:271-335.

Hara, T.J, Law, Y.M.C. and Hobben, B.R. (1973) Comparison of the olfactory response to amino acids in rainbow trout, brook trout and white fish. Comp. Biochem. Physiol. 45A: 969-977.

Herrick, C.J.(1908) On the phylogenetic differentiation of the organs of smell and taste. J. Comp. Neural. 18: 157-166.

Hildebrand , M(1974). Analysis of vertebrate structure . John Willey and Sons. Newyork.

Holl, A.(1965) Vergleichende morphologische und histologische unter suchungen am Ceruchsorgan der Knockenfische. Z. Morphal. Oekol. Tiere 54: 707-782.

Holl, A (1973) Funktion morphologie der nase von Chimaera monstrosa (Holoaphali). Z. Morphal Oekol Tiere 74: 271-296.

Hopkins, A.E.(1926) Olfactory receptors in vertebrates. J. Comp. Neural. 41: 253-289.

Ichikawa, M and Ueda, K (1977) fine structure of the olfactory epithelium in gold fish, Carassius auratus: study of the retrograde degeneration. Cell Tissue Res 183: 445-455.

Iwai, T and Nakamura , I(1964) Olfactory organ of Tunas, with special reference to there systematic significance. Bulletin of Misaki Marine Biological Institute. Kyoto University. Z: 1-8.

Jagodowski, K.P.(1901) Zur frage nach der Endigung des Geruchsnerven bei den knochenfischen. Anat. Anz. 19: 257-267

Johnson, H.E and Brown, C.J.D. (1962) Olfactory apparatus in the black rockfish, Sebastodes melanops, Copeia. 1962: 838-840.

Kapoor, A.S and Ojha, P.P(1972,a) Functional anatomy of olfactory organ in the moray, Muraena undulata Japan J. Ichthyol 19:82-88.

Kapoor, A.S and Ojha, P.P(1972,b) Studies on the ventilation of the olfactory chambers of fishes with a critical revolution of the role of accessory nasal sacs. Arch, Biol, (Liege) 83: 167-178.

Kapoor, A.S and Ojha, P.P(1972,c) Occurrence of synapsis in olfactory epithelium of fish. Experientia 28: 64-65

Kapoor, A.S and Ojha, P.P(1973,a) Functional anatomy of the nose and accessory nasal sacs in teleost, Channa punctatus, Bloch, Acta. Anta 84: 96-105.

Kapoor, A.S and Ojha, P.P(1973,b) The olfactory apparatus in the flat fish, Cynoglossus oligolepis. Trans Am. Micros. Soc. 92(2): 298-304.

Kapoor, A.S and Ojha, P.P(1974) Histology of the olfactory epithelium of the fish, Channa punctatus Bloch Acta Anta 87: 534-554.

Kashiwayanagi, Makoto, Kimie Sai and Kenzo Kurihara (1987) Cell suspensions from porcine olfactory

mucosa: Changes in membrane potential and membrane fluidity in response to various odorants, J. Gen Physial. 89(3): 443-458.

Kleerekoper, H(1969) Olfaction in fishes. Indian University Press; Bloomington.

Kleerekoper, H and Erkel, G.A. Van (1960) The olfactory apparatus of Petromyzon marinus Cenad. J. Zool, 38: 209-223.

Kolmer, W. (1927) Gerich sorgan. In: W. Von. Mollendorf Handbuch der mikroskopischen anatomic des menschen. Ed. 3(1): S192-249. Berlin.

Kubiak, H.(1962) The blood vessels in the olfactory organs in the silver beam, Blicca biorkua, Acta Biol. Cracoviensia. Ser. Zool. 5: 57-66.

Kyle, H.M. (1899). On the presence of nasal secretory sacs and a nasopharyngeal communication in teleosts with special reference to Cynoglossus. Semilaevis. Gthr. J. Linn. Soc. Zool. 27: 541-556.

Laibach, E. (1937). Das Geruchsorgan des Alas (Anguilla vulgaris) in Seiner Verschiedenen Enwick lungstadken, Zool. Jahrb, Abt. Anat. 63: 37-72

Lagler, K.f,Bordach, J.E. and Miller, R.R. (1962). Ichythyology . John wiley & Sons , Inc. New York, London 445 pp.

LeGros Clark, W.E. (1957) Inquires into the anatomical basis of olfactory discrimination. Proc Roy. Soc. B 146: 299-319.

LeGros Clark, W.E and Warwick, R.T.T. (1946) Pattern of olfactory innervations. J. Neural, Neurosura Psuchaiatr. 9: 101-111.

Liermann. K (1933). Uber den Bau des Geruchsorgans der teleostier. Z. Anat. Enwicklungsgeschichte 100: 1-39.

Lowe, G.A. Maclcod (1975) The ultrastructural organization of the olfactory epithelium of two species of ganoid fish. J. Fish.Biol 7: 29-532.

Malyukina, G.A. Dmitrieva, N.G. Marusov, E.A. and Yurkevich, G.V.(1969) Smell and its role in the behavior of fish. Zoologiva 1968: 32-78.

Marshall, N.B.(1967). The olfactory organ of bathy-pelagic fishes. Symp. Zool. Soc London 19: 57-70.

Matthes,E.(1934), Geruchsorgan. In Handbook der vergleichjenden Anatomie der weibeltiere Vol, 2, pp 897- 948 Ed.l. Bolk, E. Groppert, E. Kalliusn and W. Lubosch Urban and Schwarzenberg; Berlin.

Morril, A.D.(1898). Innervation of the olfactory eithelium. J.Comp. Neurol 8: 180-182.

Moulton D.G.and Beidlesra, L.M. (1967). Structure and function in the peripheral olfactory system. Physiol, Rev. 47: 1-52

Nogel, W. (1894). Verglichend physiologischhe und 441

Neuhaus,W.(1955) Du form der Riechzellen des Hundes, Naturwissenschaften 42:374-375.

Norman, J.R. (1963) History of fishes. fourth edition. Ernest Benn Ltd London 398 pp

Ojha, P.P and Kapoor, A.S. (1973, a) Structure and function water of the olfactory apparatus in the fresh water carp, Labeo rohita Ham Busch. J. Morphol. 140 (1): 77-86.

Ojha, P.P and Kapoor, A.S. (1973, b) The anatomy of the olfactory organs in the hill stream fish Glyptothorox telchitta Ham; with notes On its relationship with the mode of life of fish . Zool . Polo.22(4): 287 - 295.

Ojha, P.P and Kapoor, A.S. (1974). Structusre and function of the olfactory ;organ in the fish sissor rhabdophorus Ham. Acta. 87: 124-130.

Ottoson, D. (1963) Some aspects of the function of; the olfactory system. Pharmac. Rev.15: 1-42.

Pandey, K.C and Misra, R.C (1980) Olfactoray apparatus of a fresh water carp. C mrigala (HAM). Sei and Environ. II: 41-47.

Parker, G.H.(1910) Olfactory reaction in fish. J. Exp. Zool. 8:535-542.

Parker, G.H. (1911). The olfactory reactions of the common killfish. Fundulus beteroclitus. J. Exp. Zool. 10: 1-5

Parker G.H. (1912) The reaction of smell, taste and the common chemical sense in vertebrates Proc. Acad. Notl. Sci. Philadelphia. 15: 221-234.

Pfuffer, W. (1963). The morphology of; the olfactory organ of; the pacific Salmon (Oncorynchus). Can. J. Zool 41: 1233-1236.

Pfuffer, W. (1964). The morphology of; the olfactory organ of Hoploparqus guentheri Gill. 1862. Can. J. Zool. 42: 235-237.

Pfuffer, W. (1968) Das Geruchsorgan der Polypteridae (Pisces; Brachiopterygii). Z. Morphol. Ockol. Tiere. 63: 75-110.

Pfuffer, W. (1969) Der Geruchssinn der Polypteraidae (pisces; Brachiopterygu). Z. Veragluch Physiol. 63: 151-164.

Pipping, M. (1926) Der Geruchssinn der fish mitbesonderer Besraucksichtigung seiner Bedeutug fur das Aufsuchen des Futters. Soc. Sci. Fennica Commentat. Biol. 2(4): 1-28.

Popova, N.I. (1966) Sravnitel naya gistokhimicheskaya Kharakteristika muko polisakharidav obonyatel noivystilki nekotorykh nozvonochynkh (A comparative histochemical characterization of the flowery polysaccharides; of the olfactory lining in some vertebrates). Izv. Sib. Otdel. Akad Nauk, USSR. Ser. Biol No. 12 Pt 3(Rz. Biol, 1967, 67 I 653).

Porter, K.R and Bonneville, M.A. (1964) An introduction to the fine structure of cells and tissues. Lea and Febinger, Philadelphia.

Rahamani, A.R. and Khan, S.M. (1977) Functional Morphology of the olfactory organs of Anabas testudineus Block J. Zool. Res, 1 (2):53-60.

Rahmani, A.R. and Khan, S.M. (1980) Histology of the olfactory epithelilum and the accessory nasal sacs of an anabantoid fish, Anabas testudineus Bloch. Arch Biol.(Bruxelles). 91: 397-331.

Rahmani, A.R. and Khan S.M (1981) The olfactory organ in few; Indian teleosts. Curr. Sci 50(7):329-331.

Rizvi, N. (1981) Studies on the anatomy and histology of olfactory organs of certain fishes. Ph D. Thesis. Aligarh Muslim University, Aligarh India.

Rasen, M. W. and Cornford, N.E. (1971) Fluid friction of the fish slives. Nature, 234: 49-51.

Ross, M.H and Reith, E.J. (1985) Histology: A text and atlas. Harper and Row, Pubishers, Inc, 10 East, 53d street Newyork. NY 10022.

Schultze, M. (1856). Uber die Endigungsweise des Geruchsnerven und die Epithelialgebilde der Nasenschleimhaunt Monatsber. Konigl. Preuss Akad Wiss, Berlin 504.

Schultze, E. and Holl, A. (1971) Feinstruktur des Riechepithels Von Calamoichthys calabaricus. J.A. Smith (Pisces, Brachiopterygii) Z Zellforsch. Microskop. Anat. 120: 261-279.

Schaeffer. J.P. (1932) The mucous membrane of the nasal cavity and the paranasal sinuses, in COWDRY special cytology, Vol. 1.pp. 105-129 (Hocber Newyork).

Seifert, K. (1968) Die Feinstruktur des Reichsaumes. Arch. Klin. Exp. Ohr = Nas = U. Kehlk. = Heilk. 192: 182-213.

Sharma, V.I. (1981). Studies on the anatomy and histology of olfactory organs of certain teleosts, Ph.D. Thesis. Aligarh Muslim University, Aligarh India.

Sharma, V.I., Dr. Sultan Salim and Chauhan Mahesh (1999). Sustainable Development of fisheries: Emerging trends In U.P. Inland fish Soc. India 31(2): 79-84.

Sharma, V.I., Dr. Sultan Salim and Chauhan Mahesh (In Press) Inland Fisheries Society of India Barrackpore.

Sheldon, R.E.(1911) The sense of smell in Selachian. J. Exptl Zool. 10 :51-62.

Shibuya, T. (1960). The electrical responses of the olfactory epithelium of some fishes. Jap. J. Physiol. 10: 317-326.

Singh, C.P. (1972) A comparative study of olfactory organ of some Indian fresh water teleostean fishes. Anat. Anz. 131: 225-233.

Singh D.P. (1992). Histochemisrty of the olfactory organ of certain fresh water fishes. Ph.D Thesis. Bundelkhand University Jhansi, India.

Singh S.P. (1967) Histology and Histochemistry of the olfactory epithelium of certain fresh water teleosts Indian. J. Zootomy. 8: 87-108.

Singh, W. and Singh, H.R. (1986) Comparative histology of the olfactory epithelium of Barilius bendelisiss (Ham) and Pseudecheneis sulcatus (McClelland) in relation to there ecological habitats.

Singh, R.R, Singh, S.P. and Singh S.B. (1996) Functional anatomy of the olfactory organ of Illesha motives (Ham). Him J. Env. Zool. Vol. 10: 17-18.

Singh, R.K. and Singh, A.K. (1986). Morphology and Anatomy of the olfactory organs in a merine fish. Sphyraena jello (C).

Smith, R.E. and Horwitz, B.A. (1969). Brown fat and thermogenesis. Physiol.Rev. 49: 330.

Saphie Pereyaslawzeff (1876). Inaqu. Dissert. Zurich. (Quoted by Burne 1909).

Stone, H, Williams, S.B. and Carregal, E.J. (1968) The role of the trigerminal nerv in olfaction. Exp Neural.21: 11-19.

Teichmann, H. (1954) Vergbicheude Untersuchungen an der Nase der Fische. Z. Morphol. ochol tiere 43: 171-212.

Teichmann, H (1957) Das Reachvermogen des Hales (Anguilla anguilla), Naturwissenschoften 44, (7).

Teichmann, H. (1959) Uber die Leistung des Geruchssinnes beim Aal (Anguilla anguilla) Z. Vergl. Physiol. 42.3 (RZ boil, 1961, 121402).

Theisen, B. (1972) Ultrastructure of the olfactory epithelium in the Australian lung fish. Neoceratodus Forsteri. Acta. Zool. (Stockholm) 53: 205-218.

Theisen, B., Breucker, H. Zeiske, E and Melinkat, R. (1980) Structure and development of the olfactory organ in the garfish, Belone belone (L) (Teleostes. Atheriniformes). Acta Zool (Stock) 61: 161-170.

Thornhill, R.A.(1967) The ultrastructure of the olfactory epithelium of lamprey Lampetra Fluviatilis J. Cell. Sci. 2: 591-602.

Thornhill, R.A.(1972) The ultrastructure of the accessory olfactory organ in the river lamprey (Lampetra Fluviatilis). Acta Zool 53: 49-56.

Trujillo-Cenoz, O. (1961) Electron microscope observation on chemo and mechanoreceptor cells of fishes. Z. Zellf. Mikroskop, Anant 54: 5.

Tucker, D (1963) Olfactory Vomeronasal and trigeminal receptor responses to odorants. In

olfaction and tast, pp 45-69. Ed. gy Zotterman. Pergamon Press; Oxford. II

Uexcull, J. (1895). Vergleichendsinnenphisiologische undersuchungen l.Uber die Nahrungsaufnahme des katzenhaies. Z. Biol. 32: 548-566.

Vinnikov, Y.A.(1956) Structure of the organ of smell. Arkh. Anat. Gistol. Embriol. 33: 49-54.

Waghray,Sarala(1986) Olfactory organ and its sexual dimorphism in the electric ray. Narcine timelei. Ind. J. Fish. 32(1): 148-151.

Watling, H and Hillemann, H.H (1964) The development of the olfactory apparatus of the gray ling (Thymallus arcticus). J. Fish. Res. Board, Lan. 21, 2 (RZ Biol, 1965, 118).

Wilson, A.F. and Westermann, K.A. (1967). The fine structure of the olfactory mucosa and nerve in the teleost Carassius carassius. Z. Zellfors, 88: 196-206

Wunder, W. (1957) Die Sinnesorgane der Fische. Allgem Fischereizeitung. 82: 171-173.

Yadav, O.P (1989) Histomorphological studies of the olfactory organ of some fresh water Indian teleosts. Ph. D Thesis Buldelkhand University, Jhansi. India.

Yammoto, M and Ueda, K (1977) Comparative morphology of fish olfactory epithelium-I. Salmoniformes. Bull. Jap. Soc. Sci. Fish 43(10): 1163-1174.

Yammoto, M and Ueda, K (1978, a). Comparative morphology of fish olfactory epithelium–II Clupeiformes. Ibid. 44(8): 855-859.

Yammoto, M and Ueda, K (1978, b). Comparative morphology of fish olfactory epithelium – III Cyprimni-formes. Ibid. 44(11): 1201-1206.

Yammoto, M and Ueda, K (1978, c). Comparative morphology of fish olfactory epithelium – IV Anguilli-formes. Myctophiformes. Ibid. 44(11): 1207-1212.

Yammoto, M and Ueda, K (1978, d). Comparative morphology of fish olfactory epithelium – V Gasterosteiformes, Channiformes and Synbranchiformes. Ibid. 44(12): 1309-1314.

Yammoto, M and Ueda, K (1978, e). Comparative morphology of fish olfactory epithelium – VI Siluriformes. Zool. Mag. 87: 254-261.

Yammoto, M and Ueda, K (1978, f). Comparative morphology of fish olfactory epithelium – VII Gadiformes Laphiiformes and Gobiesociformes J. Fac. Sci. Sec. IV. 14: 115-125.

Zeiske, E, Melinkat, R. Breucker, H and Kuv, J. (1976) Ultrastructural studies on the epithelium of the olfactory organ of Cyprinoids(Teleostei:Cyprinodontidae) Cell. Tiss. Res. 172: 245-267.

Yammoto, M and Ueda, K (1978, a). Comparative morphology of fish olfactory epithelium–II Clupeiformes. Ibid. 44(8): 855-859.

Yammoto, M and Ueda, K (1978, b). Comparative morphology of fish olfactory epithelium – III Cyprimni-formes. Ibid. 44(11): 1201-1206.

Yammoto, M and Ueda, K (1978, c). Comparative morphology of fish olfactory epithelium – IV Anguilli-formes. Myctophiformes. Ibid. 44(11): 1207-1212.

Yammoto, M and Ueda, K (1978, d). Comparative morphology of fish olfactory epithelium – V Gasterosteiformes, Channiformes and Synbranchiformes. Ibid. 44(12): 1309-1314.

Yammoto, M and Ueda, K (1978, e). Comparative morphology of fish olfactory epithelium – VI Siluriformes. Zool. Mag. 87: 254-261.

Yammoto, M and Ueda, K (1978, f). Comparative morphology of fish olfactory epithelium – VII Gadiformes Laphiiformes and Gobiesociformes J. Fac. Sci. Sec. IV. 14: 115-125.

Zeiske, E, Melinkat, R. Breucker, H and Kuv, J. (1976) Ultrastructural studies on the epithelium of the olfactory organ of Cyprinoids(Teleostei:Cyprinodontidae). Cell. Tiss. Res. 172: 245-267.

Zeiske, E. Kux, J and Melinkat, R. (1976, a) Development of the olfactory organ of oviparous and viviparous Cyprinodonts (Teleostei). _Z. Zool. Syst. Evolut. Forsch._ _14_: 34-40.Zeiske, E, Breucker, H. and Melinkat, R. (1979)Gross morphology and fine structure of the olfactory organ of rainbow fish (Antheriniformes, Melanotaeniidae). _Acta Zool_ (Stockh). _60_: 173-186.